

The M5 East motorway is a 10 km long, four-lane dual carriage motorway, which links central Sydney with Sydney's southwest. Four kilometres of the M5 East motorway is a tunnelled section which is ventilated via a single exhaust stack, located in Turrella. The tunnels opened to traffic in December 2001 and are used by over 82 000 vehicles daily, with 6.9 per cent being heavy vehicles.

In the first half of 2002, immediately after the opening of the M5 East tunnels, NSW Health received over 80 complaints from local residents who believed their health was being adversely affected by the M5 East stack exhaust. Monitoring in the local area showed that the levels of measured pollutants had not changed from before the tunnel opening to after the tunnel opening. Following consultation with key stakeholders and experts, NSW Health developed a multi-phase investigation strategy to examine the health concerns and symptoms of the local residents.

In April and May 2003 physicians from the Royal Prince Alfred Hospital, in conjunction with officers of NSW Health, undertook the first phase of the investigation. This phase formed a base for the second

phase of the investigation by identifying which symptom(s) reported by concerned local residents had a potential relation to the M5 East stack. Symptoms of eye, nose and throat irritation were identified as having an apparent association with the stack warranting further investigation.

Following advice from epidemiologists, respiratory physicians and environmental health professionals, it was decided that the second phase of the investigation should be a cross-sectional analytical study. This study would compare the prevalence of eye, nose and throat symptoms in the local community across different exposure areas. These areas were defined according to their estimated level of exposure to stack emissions.

In July 2003 the protocol for this second phase of the investigation was submitted to the Ethics Review Committee (Southern Section) of South Eastern Sydney Area Health Service and the Ethics Review Committee of the Central Sydney Area Health Service. Approval to proceed with Phase 2 was granted in August and September 2003 respectively.

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Objectives

The objectives of this study were:

- 1 To measure the prevalence of eye, nose and throat symptoms, as identified in the Phase 1 study, in the community around the M5 East stack.
- 2 To determine whether the prevalence of symptoms is associated with the level of modelled pollutant exposure from the M5 East stack.
- 3 To determine whether further epidemiological investigation of possible health effects is indicated.

We undertook a cross-sectional survey among adults living in the vicinity of the M5 East stack. The survey was designed to compare the prevalence of eye, nose and throat symptoms between zones with relatively low, medium and high exposure to modelled M5 East stack emissions, so that an exposure-response relationship could be explored.

Symptoms of interest, identified in Phase 1, related to eyes (soreness, scratchiness, dryness, grittiness, burning and watering), the nose (itchiness, sneezing, dryness, runny, congestion) and throat (soreness, dryness).

3.1 Study area and eligible population

The study area was defined as a 6 km x 6 km region centred on the M5 East stack. This ensured an adequate number of households for the study including areas relatively free of exposure from M5 East stack emissions. The eligible population were permanent residents of the study area aged over 17 years.

3.2 Assessment of exposure in the study area

Modelling of exposure emissions from the M5 East stack was based on in-stack hourly averaged data from February 2002 to January 2003. This information was supplied by the Roads and Traffic Authority (RTA) and included: number of fans operating; volume flow rate; temperature; concentrations of fine particles with a diameter small than 10 micrometres (PM_{10}) and oxides of nitrogen (NO_x).

Background pollutant concentrations were determined by four continuous monitoring stations around the M5 East stack (T1, U1, X1, CBMS). These monitoring stations provided continuous five-minute averages of pollutant and meteorological data.

Modelling was undertaken using The Air Pollution Model (TAPM) version 2.3.

The pollutants modelled included particles (PM_{10}), oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOC). As there was no in-stack data for NMVOC, a fleet averaged NMVOC/ NO_x ratio of 0.69 was used.

The modelling consisted of two separate steps:

- **Modelling of stack emissions** – Stack emissions were modelled using the in-stack data supplied by the RTA and meteorological data supplied from the four monitoring stations.
- **Modelling of background pollutant levels** – A background concentration (ie a concentration free of stack emissions) was calculated by determining the hourly average pollutant concentrations upwind of the stack.

Concentrations of pollutants were modelled to generate ground level exposure contours. The annual average, annual daytime average, annual night-time average, highest one-hour and 10th highest one-hour emissions were modelled for the three pollutants. Appendix A contains a complete description and outputs from this modelling.

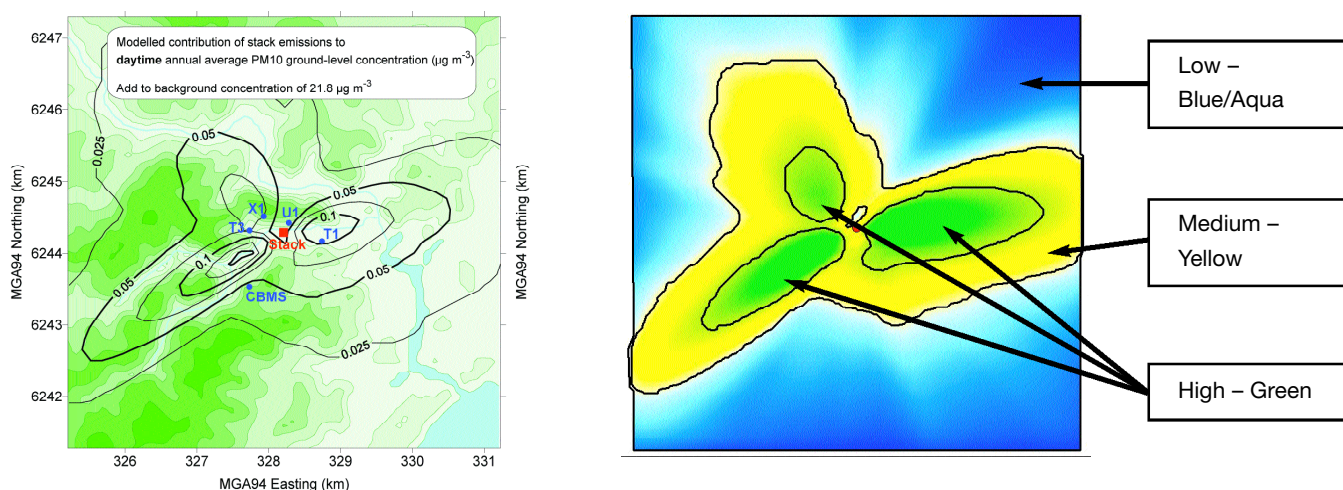
3.3 Definition of study exposure zones

The modelled annual ground level concentrations of oxides of nitrogen from the M5 East stack were used to delineate three exposure zones using ERMapper v6.4 image processing and enhancement software:

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|----------------------|--|
| High exposure zone | greater than $0.36\mu\text{g}/\text{m}^3$ NO_x |
| Medium exposure zone | between $0.20\mu\text{g}/\text{m}^3$ and $0.36\mu\text{g}/\text{m}^3$ NO_x |
| Low exposure zone | less than $0.20\mu\text{g}/\text{m}^3$ NO_x |

Modelling of the 10th highest one-hour stack emissions demonstrated a similar geographical pattern.

Figure1: Modelled contours of annual ground level concentrations of oxides of nitrogen from stack emissions, and assigned exposure zones.



3.4 Sampling strategy for the telephone survey

The target population for the survey was all residents living in households with private telephones located within the three identified exposure zones. To accurately locate residences in the three exposure zones full address records from the Australia on Disk electronic Residential White Pages were geocoded using MapInfo MapMarker v8.0 software³. Geocoded households were then assigned to exposure zones using MapInfo Professional v6.5 software⁴. The resulting lists of residential telephone numbers in each exposure zone were randomly sorted and supplied to the Computer Assisted Telephone Interview (CATI) facility for survey interviewing.

The high exposure zone consisted of 2,361 households, the medium exposure zone 7,658 households and the low exposure zone 25,637 households.

3.4.1 Sample size calculation

The sample size required to give 80 per cent power (with 95 per cent confidence) to detect a difference of 6 per cent or greater in the prevalence of dry eyes between two exposure zones was calculated using PASS2000⁵. The assumed baseline prevalence of dry eyes was 10 per cent. The estimated sample size required was 524 in each exposure zone, that is 1572 in total.

3.5 Administration of the telephone survey

Telephone interviews were undertaken using the NSW Health Survey methodology⁶. Each selected household received a letter advising them that they had been selected to participate in a 'local health survey' approximately one week before initial telephone contact. A 1800 freecall contact number was provided for potential respondents to verify the authenticity of the survey and to ask any questions regarding the survey. Trained interviewers at the NSW Health Survey (CATI) facility carried out the interviews. Up to seven calls were made to make initial contact with a household. Once the household was contacted the number of persons occupying the household who were over 17 years old was determined. One person from this number of persons was then randomly selected to take part in the study. If the person selected was unavailable at that point in time, an appointment was made to speak with that person at a later date. Up to five calls were made in order to contact the selected respondent. The questionnaire was administered in English, Greek, Italian and Chinese.

Telephone interviews were conducted by the NSW Health Survey CATI facility from October 1 to November 18 2003⁷. As questions on the symptoms of

* Interviews in languages other than English were undertaken until 21 December 2003. No difference was found between including or excluding these interviews from the data set.

interest related to the participants' experience in the previous four weeks, the telephone survey assessed symptomatology during Spring 2003.

3.6 Outcome assessment – questionnaire

The questionnaire for this survey was designed to assess the primary outcome measures (symptoms) and also to measure those factors that could confound or modify any potential association between the exposure zones and these outcomes.

Principal outcome measures were eye, nose and throat symptoms. Potential confounders were age, sex, exposure to cigarette smoke and the presence of internal garaging* and potential effect modifiers were age, general health, asthma and time spent at home.

Questions on demographics, general and mental health, asthma, chemical sensitivity, smoking status and household characteristics such as environmental tobacco smoke exposure, garaging of vehicle and home heating were taken from the NSW Health Survey⁷. By using questions that were consistent with the NSW Health Survey comparisons between the survey area and the state could be undertaken.

Questions on eye symptoms were developed using the McMonnies Dry Eye Questionnaire⁸. Questions on environmental worry were developed from Lipscomb et al⁹ and Shusterman et al¹⁰. The research team developed questions on nose, throat and mouth symptoms, time usually spent at home, awareness of the study and odour. (See attached questionnaire Appendix B)

3.6.1 Eye, nose, throat and mouth

The McMonnies Dry Eye Questionnaire is a standardised and validated dry eye questionnaire that has been used extensively in Australian dry eye and contact lens research. Its primary focus is the detection of dry eye symptoms and their possible causes. Causes of dry eye include contact lens wear, medication use, thyroid problems and lifestyle habits. Eye symptoms

from this questionnaire (soreness, scratchiness, dryness, grittiness, burning and watering*) were modified to allow for in-depth analysis. This modification was consistent with that used by the Cornea and Contact Lens Research Unit, University of NSW to include an assessment of frequency (constant, often, sometimes, never) and severity (mild, moderate, severe). Questions on the use of eye drops were excluded from our questionnaire due to the difficulty of assessing such information via a telephone survey. Questions on arthritis were also excluded to keep the survey to a reasonable length of time. The exclusion of these questions from the McMonnies instrument required an adjustment of the referent value for dry eye diagnosis from 14.5 to 12.

Following consultation with leading clinical researchers we developed questions to assess symptoms related to the nose (itchiness, sneezing, dryness, runny, congestion) and throat (soreness, dryness). Frequency and severity of these symptoms were assessed using the same format as for eye symptoms.

We also included a question related to symptoms of 'teeth and gums' to assess bias arising from possible awareness of the purpose of the study.

To minimise recall bias, participants were asked to only report on symptoms experienced within the last four weeks.

3.6.2 Demographics and household characteristics

In order to describe the demographic profile of the community around the M5 East stack, participants were asked general questions about themselves and their lifestyle. The questions included age, sex, confirmation that the respondent lived in the study area, length of residency, language spoken at home, country of birth, home owner or renter, employment status and education level. In addition questions on possible indoor pollution sources such as smoking, garaging of vehicle and home heating were included.

* Internal garaging has been linked with increased levels of the motor vehicle pollutant benzene in the household. (National Industrial Chemicals Notification and Assessment Scheme (NICNAS) *Benzene – Priority Existing Chemical Assessment Report No. 21* NICNAS 2001)

* Eye watering symptom does not appear in the McMonnies Questionnaire. This symptom was added as a result of Phase 1 of the investigation.

3.6.3 General health

This section consisted of three standardised and validated questions about the participants' general health from the NSW Health Survey. These questions were adopted as self-rated health is a fundamental measure of health status and health outcomes and is believed to principally reflect physical health problems. By asking these questions we were able to gain an insight into the self-rated general health status of the participants living in the three exposure zones and compare these rates to the rest of NSW. The general health rating was determined from the question

Overall, how would you rate your health during the past 4 weeks: Excellent, Very Good, Good, Fair, Poor, Very Poor?

The prevalence reported in the result section represents those who answered either excellent, very good or good to this question. This is consistent with how general health is assessed in the NSW Health Survey.

3.6.4 Mental health

Mental health was measured using the Kessler 6 (K6) mental health questionnaire. The K6 is a truncated version of the Kessler 10 (K10) and scores from both scales are comparable. The K6 is a six-item self-report questionnaire intended to determine a global measure of 'psychological distress' based on questions about the level of restlessness, anxiety, and depressive symptoms in the most recent four-week period. It is designed to span the range from few or minimal symptoms through to extreme levels of distress. It is extensively used around the world in general health surveys. The NSW Health Survey uses the K10 as its mental health instrument. This has allowed a comparison of self-reported mental health amongst the M5 East stack community with that of the general NSW population. Our survey used the K6 and not the K10 to keep the survey to a reasonable length of time. The prevalence of those rated with high or very high psychological distress is represented in the results section.

3.6.5 Asthma

The asthma questions were taken directly from the NSW Health Survey. They are designed to determine asthma prevalence, allowing the comparison of asthma prevalence around the M5 East stack with the rest of the state. The questions on asthma were undertaken as asthma is known to be associated with air pollutants. The prevalence of asthma in the results section was determined by answering 'yes' to the following questions

Have you ever been told by a doctor or at a hospital that you have asthma: Yes, No?

Have you had symptoms of asthma or taken treatment for asthma in the last 12 months: Yes, No?

3.6.6 Chemical sensitivity and odour

Multiple chemical sensitivity is most usually defined as a chronic condition, with symptoms that recur in response to low levels of exposure to multiple unrelated chemicals and improve or resolve when those unrelated chemicals are removed¹⁰. As there was an unknown relationship with multiple chemical sensitivity and the M5 East stack, chemical sensitivity questions from the NSW Health Survey were included so that self-reported prevalence of chemical sensitivity within the M5 East community may be compared with that of the state. This prevalence was based on the following question:

Have you ever been diagnosed with a chemical sensitivity: Yes, No?

Participants were also asked to rate the frequency and annoyance of any foreign odours they had noticed when they were at home. The prevalence of odour in the results section is based on the question:

How often do you notice odours or smells from outside sources when you are at home or in your yard: Every day, A few days a week, A few days a month, Never?

The prevalence of participants who answered either every day or a few days a week is reported in the results section.

3.6.7 Exposure time

To account for differential exposure due to the time spent within the designated zone, a question was introduced that asked about the proportion of the day typically spent at home.

Which of the following phrases best describes where you spend most of your time: I live here and spend most of my time at this address, I live here but work or study elsewhere, I spend little time at this address?

The rate presented in the results section represents the participants that live and spend most of their time at their address.

3.6.8 Environmental worry

Environmental worry has been documented previously in studies of this type^{9,10}. The questions enquire into the participants' concern about environmental hazards in their neighbourhood. Participants are invited to rate their level of worry and then specify if they felt these environmental hazards had affected their health. The prevalence of environmental worry was generated from the following question:

How worried or concerned are you about any environmental hazards in your neighbourhood: Not at all, Somewhat worried, Very worried?

The results section reports the prevalence of 'very worried' only.

3.6.9 Did the participant realise this study was about the M5?

The survey was described to participants as a 'local health survey' in an attempt to minimise bias that could arise out of participants being aware of its purpose. If however the participant asked the interviewer if the survey related to the M5 East stack investigation the interviewers were instructed to confirm this. The interviewer was instructed to then note this fact with the participants' responses. The *Aware* category in the results section is the percentage of those interviewed for whom the interviewer noted this fact on their questionnaire.

3.7 Analysis

The survey sample was weighted to adjust for the differences in the probabilities of selecting a particular person in a household, based on the number of eligible adults in that household. Post stratification weights were used to reduce the effect of differing non-response rates among males and females and age groups on the survey estimates. These weights were adjusted for differences between the age and sex structure of the survey sample and population estimates for each exposure zone. Further information about the general weighting process is provided elsewhere⁶. The population estimates were derived from Australian Bureau of Statistics 2001 Census Community Profiles Series¹². Zone populations were estimated by the allocation of collector district populations to the zone in which collector district centroids were located.

Design-based analysis was performed to account for features of the sample design¹³ and provide approximately unbiased estimates and appropriate standard errors¹⁴. Call and interview data were manipulated and analysed using SAS v.8.0 statistical software package¹⁵. The SURVEYMEANS procedure was used to calculate 95 per cent confidence intervals for descriptive analysis. Additional analysis and multivariable modelling were undertaken using SUDAAN 8.0.1 statistical software package¹⁶. The SURVIVAL procedure was used for multivariable modelling with Taylor series linearization methods used for variance estimation.

The association between exposure zone and symptom outcomes was examined using Cox's proportional hazards models with constant follow-up time. This approach was used since the odds ratio, a measure of effect derived from logistic regression models, is a poor estimate of the risk ratio with common outcomes (>10 per cent)^{17,18}.

The independent predictor of exposure zone was modelled as a categorical variable using the low zone as the reference category. The following covariates were included in the multivariable analysis as clinically relevant confounders: sex, age in years (continuous scale), exposure to cigarette smoke (exposed/unexposed), and exposure to emissions from garaged vehicles (exposed/unexposed). Effect modification was tested for clinically plausible effect modifiers: current asthma (yes/no), general health (excellent, very good, good/fair, poor) and age group.

The analysis comprised two major areas:

1 Profile of the zones compared to each other and the state where possible –

Age, sex, education level, general health (rated good or above), mental health (scored as high or very high psychological distress), asthma, indoor air pollution sources, smoking, home ownership and chemical sensitivity were compared between zones, and between the study area as a whole and NSW.

Environmental worry, exposure time, odour and awareness that the survey related to the M5 investigation, were compared across the three zones only.

2 Comparison of symptoms of interest across zones –

i Scores were calculated from individual reports of symptoms by the following method:

- a *Calculation of eye symptom/nose symptom/throat symptom scores:* If the participant answered 'yes' to any one of the six eye symptoms they were noted as having an 'Eye Symptom'. Likewise if a participant answered 'yes' to any one of the five nasal symptoms they were noted as having a 'Nose Symptom' and if a participant answered 'yes' to any of the two throat symptoms, they were noted as having a 'Throat Symptom'.

- b *Calculation of more frequent and/or severe index for eye nose and throat:* To calculate the more frequent and/or severe score, each frequency (sometimes, often, constantly) and severity response (mild, moderate, severe) was assigned a value from 1-3. The frequency and severity were then multiplied together to come up with a frequent and/or severe score. If that score was over one (that is if the participant had a symptom greater than *sometimes* of a *mild* nature) then the participant was defined as having a more frequent and/or severe eye, nose or throat symptom.

- c *Dry Eye Score:* Responses to the questions from the McMonnies Dry Eye Questionnaire were scored according to standard methodology. The dry eye prevalence was determined by a score greater than 11. Dry eye prevalence was then compared across zones, and to prevalence identified in separate studies* on the populations of Melbourne, Victoria¹⁹ and Mackay, Queensland²⁰.

ii Symptom scores were compared across exposure zones by:

- a Calculating crude point prevalence estimates with 95 per cent confidence intervals across exposure zones.
- b Calculating crude prevalence rate ratios with 95 per cent confidence intervals across exposure zones. This was done for the high and medium zones using the low exposure zone as the reference category.
- c Modelling adjusted prevalence rate ratios with 95 per cent confidence intervals. Again this was done for the high and medium zones using the low exposure zone as the reference category.

* Indicative prevalence rates only as measurement techniques varied.