Results 4

4.1 Survey participants

After a maximum of seven attempts, telephone contact was made with 2433 eligible households within the study area. As a result of these contacts, 1431 interviews were conducted with eligible participants (59 per cent participation rate). The number of participants in each zone was: high exposure zone 485 subjects (59 per cent participation), medium exposure zone 481 subjects (58 per cent participation rate), and low exposure zone 465 subjects (59 per cent participation rate). There were 75 interviews (5.2 per cent) conducted in a language other than English. The age, sex and education level of participants did not differ between the zones (Table 1).

The overall prevalence of certain common conditions in the study area was similar to that observed, using the same NSW Health Survey instrument, across the whole of NSW (Table 2).

A few of the characteristics measured in this survey did differ between the study zones (Table 2). Those that were significantly different across zones included environmental worry, the presence of internal garaging and awareness about the survey being related to the M5 East stack. Of those participants who were worried about environmental hazards (environmental worry), 48 per cent believed that these hazards had affected their health. This belief was similar irrespective of zone.

Table 1 Age, Sex and Total Participants by Zone

		High Zone (n=485)	Medium Zone (n=481)	Low Zone (n=465)	Overall (n=1431)
Age	Mean	51	51	49	50
	SD	18	17	18	17
Sex	Female%	58	57	54	57
Education Level	Year 10 (%)	24.3	24.9	25.4	25.2
	(95%CI)	*(19.7–28.9)*	*(20.4–29.3)*	*(20.6–30.2)*	*(21.7–28.7)*
	HSC (%)	23.5	21.6	23.3	22.9
	(95%CI)	*(18.1–28.9)*	*(16.6–27.1)*	*(18.4–28.2)*	*(19.3–26.5)*
	TAFE (%)	23.5	23.7	22.2	22.7
	(95%CI)	*(19.1–27.9)*	*(19.1–28.3)*	*(17.7–26.7)*	*(19.4–25.9)*
	University (%)	28.7	29.8	29.1	29.2
	(95%CI)	*(23.8–33.5)*	*(24.7–35.0)*	*(24.0–34.2)*	*(25.5–33.0)*

Table 2 Respondent Characteristics by Zone

	High Zone % (95%CI)	Medium Zone % (95%CI)	Low Zone % (95%CI)	Overall % (95%CI)	State* % (95%CI)
General Health[i]	80.0 *(75.9–84.1)*	79.6 *(75.2–84.1)*	80.9 *(77.0–84.8)*	80.5 *(77.6–83.4)*	80.7 *(79.7–81.7)*
Mental Health[ii]	12.6 *(8.7–16.6)*	13.8 *(9.8–17.7)*	13.3 *(9.6–16.9)*	13.3 *(10.6–16.1)*	12.2 *(11.4–13.1)*
Diagnosed Asthma[iii]	9.8 *(6.5–13.2)*	9.4 *(5.7–13.1)*	11.4 *(7.8–15.0)*	10.8 *(8.1–13.43)*	10.6 *(9.8–11.3)*
Environmental Worry[iv]	18.9 *(14.6–23.2)*	14.6 *(10.8–18.5)*	11.3 *(8.0–14.6)*	12.6 *(10.1–15.1)*	N/A
Exposure Time[v]	53.0 *(47.5–58.6)*	49.8 *(44.2–55.4)*	49.9 *(44.4–55.3)*	50.1 *(46.1–54.1)*	N/A
Odour Detection[vi]	22.0 *(17.5–26.5)*	23.3 *(18.4–28.1)*	24.6 *(20.1–29.1)*	24.1 *(20.8–27.4)*	N/A
Awareness of survey link to M5 stack[vii]	17.2 *(13.6–20.9)*	9.7 *(6.8–12.6)*	2.5 *(1.2–3.9)*	5.2 *(4.0–6.4)*	N/A
Indoor Heating Pollution[viii]	26.1 *(21.2–31.1)*	28.2 *(23.2–33.1)*	27.6 *(22.5–32.6)*	27.6 *(23.9–31.3)*	22.6 *(20.6–24.7)*
Home Ownership[ix]	71.1 *(65.4–76.9)*	62.3 *(56.4–68.3)*	59.7 *(54.2–65.1)*	61.1 *(57.0–65.1)*	N/A
Personal Smoking[x]	18.6 *(14.4–22.8)*	24.0 *(19.2–28.8)*	26.5 *(21.7–31.3)*	25.4 *(21.9–28.9)*	21.4 *(20.3–22.4)*
Smoke Free Households[xi]	81.5 *(77.3–85.7)*	86.2 *(82.1–90.2)*	78.9 *(74.4–83.3)*	80.8 *(77.6–84.0)*	81.0 *(80.0–82.0)*
Internal garaging[xii]	14.2 *(9.7–18.8)*	9.8 *(6.5–13.1)*	11.0 *(7.5–14.5)*	10.9 *(8.4–13.5)*	22.2 *(20.0–24.3)*
Chemical Sensitivity[xiii]	1.6 *(0.2–3.0)*	2.6 *(0.9–4.3)*	2.7 *(0.8–4.6)*	2.6 *(1.2–4.0)*	2.9 *(2.5–3.4)*
Teeth and Gums Symptoms[xiv]	18.7 *(14.5–22.8)*	21.9 *(17.3–26.6)*	18.3 *(13.9–22.8)*	19.2 *(16.0–22.5)*	N/A

* Values reported only where there are State-wide data

[i] General health rated as excellent, very good or good

[ii] Kessler 6 scored at high or very high psychological distress.

[iii] Been told by a doctor or at a hospital that they had asthma AND had symptoms of asthma or taken treatment for asthma in the past 12 months.

[iv] Prevalence of the very worried category

[v] Most of time spent at this address.

[vi] Foreign odours detected everyday or few days per week.

[vii] Participant aware that survey was about the M5 East stack.

[viii] Unflued gas heater, slow burning combustion heater, open fire place or kerosene heater being the usual way to heat areas in the home

[ix] Home owner, mortgagee, life tenure or rent / buy scheme.

[x] Participant smoked daily or occasionally

[xi] Household is smoke free

[xii] Garage is attached to house and has internal access

[xiii] Participant has been diagnosed with chemical sensitivity

[xiv] Soreness of teeth or gums constantly, often or sometimes.

4.2 Symptoms by zone

4.2.1 Eye symptoms

4.2.1.1 Prevalence

Overall, 50 per cent of people reported any occurrence of one or more of the six eye symptoms and 17.2 per cent reported one or more 'More Frequent and/or Severe Eye Symptoms'. Table 3 presents the prevalence of eye symptoms by exposure zone.

Table 3 Eye Symptoms, Frequency and Severity by Zone

	Any Eye Symptom		More Frequent &/or Severe Eye Symptoms	
	%	(95%CI)	%	(95%CI)
High Zone	50.1	(44.6–55.6)	19.9	(15.7–24.0)
Medium Zone	54.7	(49.2–60.3)	16.4	(12.6–20.3)
Low Zone	48.3	(42.9–53.7)	17.2	(13.2–21.2)
Overall	50.0	(46.0–54.0)	17.2	(14.2–20.1)

The prevalence of dry eye, classified according to the modified McMonnies Dry Eye Questionnaire, was 6.7 per cent (Table 4). This is within the range observed in two previous general population surveys in Melbourne, Victoria and Mackay, Queensland (1.5 – 16.3 per cent)*.

Table 4 McMonnies Dry Eye Prevalence by Zone

	%	(95%CI)
High Zone	5.1	(2.9–7.3)
Medium Zone	8.4	(5.3–11.4)
Low Zone	6.2	(3.6–8.8)
Overall	6.7	(4.7–8.6)

The crude prevalence rate ratios of 'Eye Symptoms' and 'More Frequent and/or Severe Eye Symptoms' did not differ between the high and low exposure zones or between the medium and low exposure zones (Table 5).

4.2.1.2 Modelling

When adjusting the crude prevalence rate ratios for the potential confounders of age, sex, exposure to cigarette smoke and internal garaging there was still no evidence of an association between zones and symptoms (Table 5).

Table 5 Crude and adjusted prevalence rate ratios for eyes.

	Any Eye Symptom		More Frequent &/or Severe Eye Symptoms	
	Crude prevalence rate ratio (95%CI)	Adjusted prevalence rate ratio (95%CI)	Crude prevalence rate ratio (95%CI)	Adjusted prevalence rate ratio (95%CI)
High Zone	1.04 (0.89–1.22)	1.05 (0.90–1.23)	1.15 (0.84–1.57)	1.16 (0.86–1.58)
Medium Zone	1.12 (0.96–1.31)	1.13 (0.97–1.31)	0.95 (0.68–1.32)	0.96 (0.69–1.33)
Low Zone	1.00 (REF)	1.00(REF)	1.00 (REF)	1.00(REF)

Prevalence rate ratio adjusted for age, sex, exposure to cigarette smoke and internal garaging. Crude prevalence rate ratios of these confounders may be found in Appendix C.

* Taken from the studies of McCarty[19] and Albertz[20]. These studies did not use the McMonnies Dry Eye Questionnaire to diagnose dry eye and are only indicative of the prevalence of dry eye.

4.2.2 Nose symptoms

4.2.2.1 Prevalence

Overall, 66.6 per cent of people reported any occurrence of one or more of the five nose symptoms and 32.9 per cent reported one or more 'More Frequent and/or Severe Nose Symptoms'. Table 6 presents prevalence of nose symptoms by exposure zone.

Table 6 Nose Symptoms, Frequency and Severity by Zone

	Any Nose Symptom		More Frequent &/or Severe Nose Symptoms	
	%	(95%CI)	%	(95%CI)
High Zone	68.9	(64.1–73.7)	37.8	(32.4–43.3)
Medium Zone	66.4	(61.0–71.6)	35.1	(29.8–40.4)
Low Zone	66.5	(61.4–71.6)	31.6	(26.7–36.6)
Overall	66.6	(62.9–70.4)	32.9	(29.3–36.6)

The crude prevalence rate ratios of 'Nose Symptoms' and 'More Frequent and/or Severe Nose Symptoms' did not differ between the high and low exposure zones or between the medium and low exposure zones (Table 7).

4.2.2.2 Modelling

Once adjusting for the potential confounders of age, sex, exposure to cigarette smoke and internal garaging there was still no evidence of an association between zones and symptoms (Table 7).

Table 7 Crude and adjusted prevalence rate ratios for nose.

	Any Nose Symptom		More Frequent &/or Severe Nose Symptoms	
	Crude prevalence rate ratio (95%CI)	Adjusted prevalence rate ratio (95%CI)	Crude prevalence rate ratio (95%CI)	Adjusted prevalence rate ratio (95%CI)
High Zone	1.04 (0.94–1.15)	1.04 (0.94–1.16)	1.19 (0.96–1.48)	1.20 (0.97–1.48)
Medium Zone	1.00 (0.89–1.11)	1.00 (0.89–1.11)	1.10 (0.88–1.36)	1.09 (0.88–1.35)
Low Zone	1.00 (REF)	1.00(REF)	1.00 (REF)	1.00(REF)

Prevalence rate ratio adjusted for age, sex, exposure to cigarette smoke and internal garaging. Crude prevalence rate ratios of these confounders may be found in Appendix C.

4.2.3 Throat symptoms

6.2.3.1 Prevalence

Overall, 33.1 per cent of people reported any occurrence of one or more of the two throat symptoms and 14.9 per cent reported one or more 'More Frequent and/or Severe Throat Symptoms'. Table 8 presents prevalence of throat symptoms by exposure zone.

Table 8 Throat Symptoms, Frequency and Severity by Zone

	Any Throat Symptom		More Frequent &/or Severe Throat Symptoms	
	%	(95%CI)	%	(95%CI)
High Zone	29.6	(24.6–34.6)	16.3	(12.1–20.5)
Medium Zone	36.6	(31.0–42.3)	17.1	(12.8–21.5)
Low Zone	32.2	(27.1–37.3)	14.0	(10.3–17.7)
Overall	33.1	(29.3–36.9)	14.9	(12.1–17.7)

The crude prevalence rate ratios of 'Throat Symptoms' and 'More Frequent and/or Severe Throat Symptoms' did not differ between the high and low exposure zones or between the medium and low exposure zones (Table 9).

4.2.3.2 Modelling

When adjusting the crude prevalence rate ratios for the potential confounders of age, sex, exposure to cigarette smoke and internal garaging there was still no evidence of an association between zones and symptoms (Table 9).

Table 9 Crude and adjusted prevalence rate ratios for throat.

	Any Throat Symptom		More Frequent &/or Severe Throat Symptoms	
	Crude prevalence rate ratio (95%CI)	Adjusted prevalence rate ratio (95%CI)	Crude prevalence rate ratio (95%CI)	Adjusted prevalence rate ratio (95%CI)
High Zone	0.92 (0.73–1.16)	0.94 (0.74–1.18)	1.17 (0.81–1.70)	1.18 (0.81–1.72)
Medium Zone	1.12 (0.90–1.40)	1.13 (0.91–1.41)	1.19 (0.83–1.72)	1.20 (0.83–1.74)
Low Zone	1.00 (REF)	1.00(REF)	1.00 (REF)	1.00(REF)

Prevalence rate ratio adjusted for age, sex, exposure to cigarette smoke and internal garaging. Crude prevalence rate ratios of these confounders may be found in Appendix C.

5 Discussion

This study has not demonstrated an association between the emissions from the M5 East stack and reports of eye, nose and throat symptoms. These results were unchanged when adjusted for potential confounders (age, sex, exposure to cigarette smoke and internal garaging). In interpreting this finding it is important to consider the strengths and the limitations of this study.

5.1 Study design

The objective of Phase 1 of this investigation was to characterise the nature of health effects that residents were experiencing and to develop a hypothesis, to be investigated in Phase 2, that these health effects were associated with emissions from the M5 East stack. A cross-sectional study design was chosen for Phase 2 as it allowed the testing of this hypothesis by comparing the prevalence of symptoms among groups at different exposure levels (zones). A limitation of this study design is that the findings may only be interpreted on a population level and not at an individual level. This study design was chosen as individual exposure measurements were unavailable and impractical for such a large study. Furthermore, the nature of any specific exposure that might be causing the symptoms was unknown.

The survey respondents were restricted to individuals older than 17 years. As few children presented for assessment in Phase 1 we were unable to formulate a case definition for children.

5.1.1 Study power and response rate

The ability of the study to establish a 'true' association between exposure and health effects (study power) is determined by the number of individuals surveyed, the prevalence of the symptom and the minimum effect size to be detected. Depending on the prevalence of the symptom, our study had enough power to be able to detect a 5 to 10 per cent or greater difference in symptom prevalence between the low and high exposure zones. Therefore any 'true difference' below this 5 to 10 per cent level will not be detected. The final number of respondents was slightly less than anticipated which resulted in a small decrease in the power of the study.

The response rates were similar across the exposure zones but were slightly lower than other studies of this nature*.

5.1.2 Exposure assessment

Exposure assessment at an individual level was not feasible for this phase of the study and consequently representative zone exposure levels were modelled. Direct monitoring of exposure levels is problematic due to the difficulty in separating relatively large background pollutant levels from predicted stack emission contributions and the lack of a hypothesis about the causative role of any specific pollutant.

Hence we chose to estimate individual's exposure to pollutants. One simple way to estimate exposure is by distance from the point source of exposure. However we considered this method not adequate for this study due to the complex nature of the study area's topography. Modelling exposure based on local measurements, known topography and meteorology provided a more valid exposure estimate. Exposure modelling used in this study was performed by an independent expert agency with considerable experience in this area, using data collected over one year of operation of the M5 East stack. We believe it represents the most feasible measure of exposure to M5 East stack emissions.

i Annual averages vs peaks

A potential limitation of the exposure assessment is that it uses modelled annual averages rather than peak levels to determine exposure zones. However given that the first phase of the study identified health effects that were relatively constant over time it is unlikely that peak emissions are the cause of these symptoms. Hence, annual averages are likely to be the more appropriate exposure measure.

* Response rate for the 1997 and 1998 Health Survey are 70.8% and 65.0% respectively.

ii Limited exposure assessment of volatiles

Exposure modelling was performed for PM_{10} and NOx without direct modelling of non-methane volatile organic compounds (NMVOC). NMVOC were modelled indirectly as a ratio of NMVOC to NOx. This was validated against representative vehicle count data for the M5 tunnel and fleet averaged emissions rates.

iii 'Proxy measure' concept

The modelled increase in levels of particles and NOx above documented background levels is in the order of one per cent. This level of increase is unlikely to explain a detectable increase in health effects and consequently it has been postulated that other compounds that are not currently being monitored might be causing the observed health effects. Should this be the case it is reasonable to presume that these unknown compounds would be distributed in the same pattern as particles and NOx. As such, particle or NOx levels were used as proxy measures for these unknown compounds.

5.1.3 Symptom assessment

Symptoms were assessed by means of a telephone survey methodology that is widely used and has been validated for the collection of health information at a community level•. Many of the questions used in this survey were the same as those used in the NSW Health Survey. This enabled us to compare the survey population with the NSW population as a whole.

Respondents were asked about symptoms occurring in the preceding four weeks. This relatively brief recall period ensures a reliable recall of events. However, if M5 East stack exposures during the specific four week recall period were not representative of exposures at other times, this may give unrepresentative results. We have data to confirm that stack emissions during the study period were representative of average year levels (Appendix D).

5.1.4 Acute symptoms and chronic health effects

The study design used was unable to assess the potential long-term or cumulative effects of M5 East stack emissions. Such an assessment would require long-term follow-up of study participants.

5.2 Potential biases

There are two main forms of bias or sources of error that might distort a study's results, measurement bias and selection bias. The study design used was subject to both these biases.

An important potential measurement bias in this study was recall bias. Recall bias occurs when the participant is unable to accurately report the extent, frequency or nature of past events. To overcome this bias, respondents were limited to reporting symptoms from the previous four weeks. Another potential form of bias would arise if respondents who were aware of the purpose of the survey, to assess the impact of the M5 East stack, had altered their responses because of this knowledge.

Selection bias may have occurred by our survey selecting out a non-representative group of the community. This may have occurred if those with unlisted telephone numbers, those without a telephone in their household or those who declined to participate in the survey were different from those who participated in the survey. Selection bias may also have resulted through our ability to only interview current residents. It is possible that previous residents experiencing symptoms may have moved away from the area, limiting our ability to detect an association between the M5 East stack emissions and symptoms. This bias due to selective migration could only have been overcome by initiating a cohort study prior to the commencement of emissions from the stack.

• Information on the NSW Health Survey may be obtained from the following website: http://www.health.nsw.gov.au/public-health/survey/hsurvey.html

5.3 Use of a group control

The study design used did not include a control group from an area entirely remote from the M5 East stack. Instead, the study relied on using the lower exposure area as a reference area and compared symptoms from the medium and high zones with this area. Comparisons with a control group from a distant area would have led to difficulties in adjusting for differences in background pollutants levels and other regionally specific factors (eg ethnicity, socio-economic status).

5.4 Adjusting for confounders and effect modifiers

Age, sex, exposure to cigarette smoke and internal garaging of motor vehicle were factors that had the potential to be associated with the eye, nose and throat symptoms. Unless these factors were equal across all zones they had the potential to confound (or distort) our results. We adjusted for these known potential confounders using Cox's proportional hazard modelling.

It is also possible that environmental pollutants may only cause symptoms under certain circumstances raising the question of effect modifiers present in the relationship between symptoms and pollutant exposure. However statistical analysis undertaken in this study found no evidence of any effect modifiers.

5.5 Environmental worry

Other environmental health studies have explored the association between environmental worry and adverse health symptoms reported in communities exposed to levels of pollutants below recognised toxic effect levels [9,10,22,23]. These studies have argued that a participant's level of environmental worry may affect how and if they report symptoms, either through direct reporting or through the worrying, helping the participant to recall symptoms that would otherwise have been forgotten. If this was the case then it may be appropriate to adjust for environmental worry in the analysis. Alternatively it could be argued that environmental worry is on the causal pathway of environmental exposure causing a health effect and therefore should not be adjusted for.

Phase 2 of the study has identified a higher degree of environmental worry in the high exposure zone than in the medium and low exposure zone. Consequently adjusting for environmental worry would have made it less likely to find an association between residence in the higher exposure zone and symptoms. We did not adjust for environmental worry in this study.