Memorandum

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Amended January 2019 to include corrections for blank (limits of detection) in BTEX results

Ambient air quality survey (PM1, PM2.5, PM10, BTEX and NOx) at Bell Block Bypass

Introduction

From 13 January 2014 to 14 March 2014 the Taranaki Regional Council carried out an ambient air quality survey at the Bell Block bypass. This monitoring was initiated to assess the impact of increased traffic movement on air quality due to expansion of commercial premises in that area. Due to the relatively high traffic flows in this area, it is considered that air quality in the vicinity likely to be lower than across most of Taranaki.

Figure 1 View of the monitoring site at PIHMS premises looking towards Bell Block Bypass

The ambient survey involved the measurements by portable meter and passive absorption tubes of the following parameters - fine particulates (PM1, 2.5 and 10), nitrogen oxides (NOx), and volatile organic compounds (focusing on benzene), toluene, ethyl benzene and xylene (BTEX). This monitoring was validated using traffic counts on SH3 at Egmont Road provided by NZTA. The findings of this 'sixth' monitoring programme in the Taranaki region are presented in this memorandum.

Methodology

- Ambient PM 1, 2.5, and 10 monitoring was conducted using a portable data logging TSI 'DustTrak DRX' at the premises of the Pacific International Hotel Management School (PIHMS) over a two month period from 13 January 2014 to 14 March 2014 (Figure 1). The instrument was logging an instantaneous measurement every second, and then converting this data to generate one minute averages, over the duration of the sampling period.

- Ambient Nitrogen Oxides (NOx) monitoring was conducted at four stationary sites spaced evenly on either sides of the Bell Block over-bridge (Figure 2) using 'eurofins ELS' passive samplers deployed for a period of three weeks. 'Field blank' and 'field spike' samplers were also assessed for this three weeks deployment.

- Ambient Volatile Organic Compounds (VOC) sampling was conducted at the same four stationary sites side by side with NOx samplers using 3M passive absorption badges.

- The traffic counting method on SH3 at the Egmont Road permanent counting site employs an induction loop in the road to record a ‘hit’ when a vehicle passes a set induction threshold over the loop in the road. This non-contact traffic counting method allows continuous recording of traffic volumes.

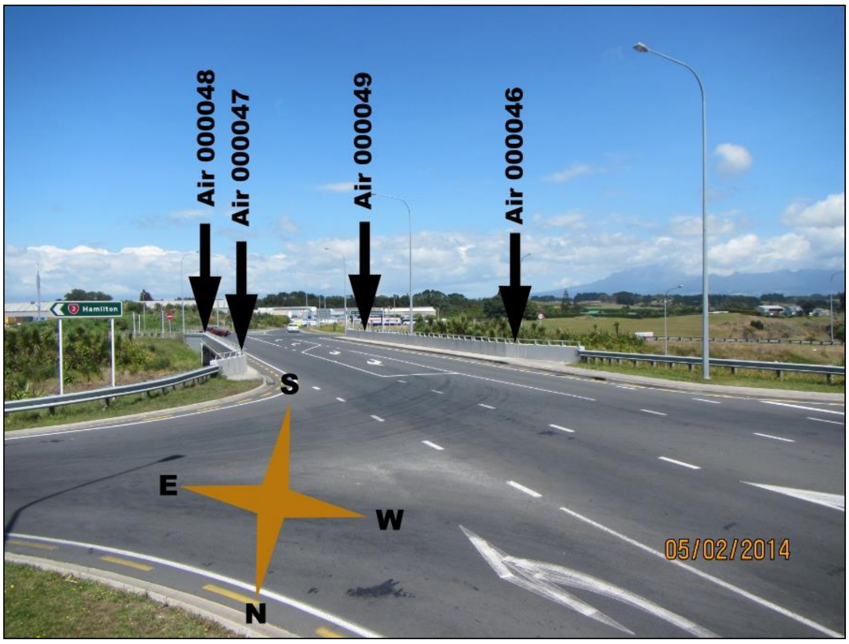

Figure 2 Four BTEX and NOx monitoring sites on Bell Block over-bridge

Meteorological conditions

The meteorological data presented in this memorandum were collected at the nearest meteorological site, located in New Plymouth airport (approximately 4 km due north-east along the coast). The wind rose covering the entire monitoring period is presented in Figure 3. The wind data displays a stable moderate/fresh breeze from west to south-east.

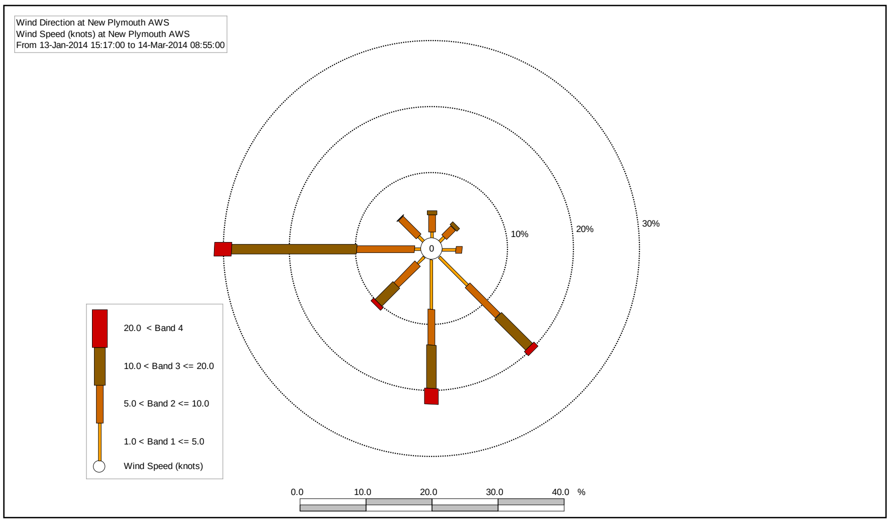

Figure 3 New Plymouth Airport wind data

PM1, 2.5 and 10 monitoring

Background

Particles found in the air we breathe vary greatly in size. The greatest health hazard from particles comes from the smallest ones – less than 10 microns (10 µm or 10 micrometres) across – because we easily inhale these small particles into our lungs. These particles are referred to as PM10 (referring to their size) or as inhalable particulate (referring to their potential effect). Health effects from inhaling PM10 include increased mortality and the aggravation of existing respiratory and cardiovascular conditions such as asthma and chronic pulmonary diseases.

Fine particulates come from sources such as burning coal, oil, wood, and petrol and diesel in domestic fires, transportation and industrial processes. Natural sources of particles include sea salt, dust, pollens and volcanic activity. In terms of comparative size, a human hair is approximately 50 microns across, while the finest beach sand is approximately 100 microns across.

Standard and guidelines for particulate

In September 2004 the Ministry for the Environment formally made public the National Environmental Standards (NES) relating to certain air pollutants. The NES for PM10 is 50µg/m³ (24-hour average). The World Health Organization (WHO) in 2006 set a guideline for PM2.5 of 25µg/m³ (24-hour average). Guideline values for PM1.0 have not been sighted.

Discussion of Bell Block bypass results

The details of the sample runs (PM 2.5 and PM10) are graphically presented in Figure 4.

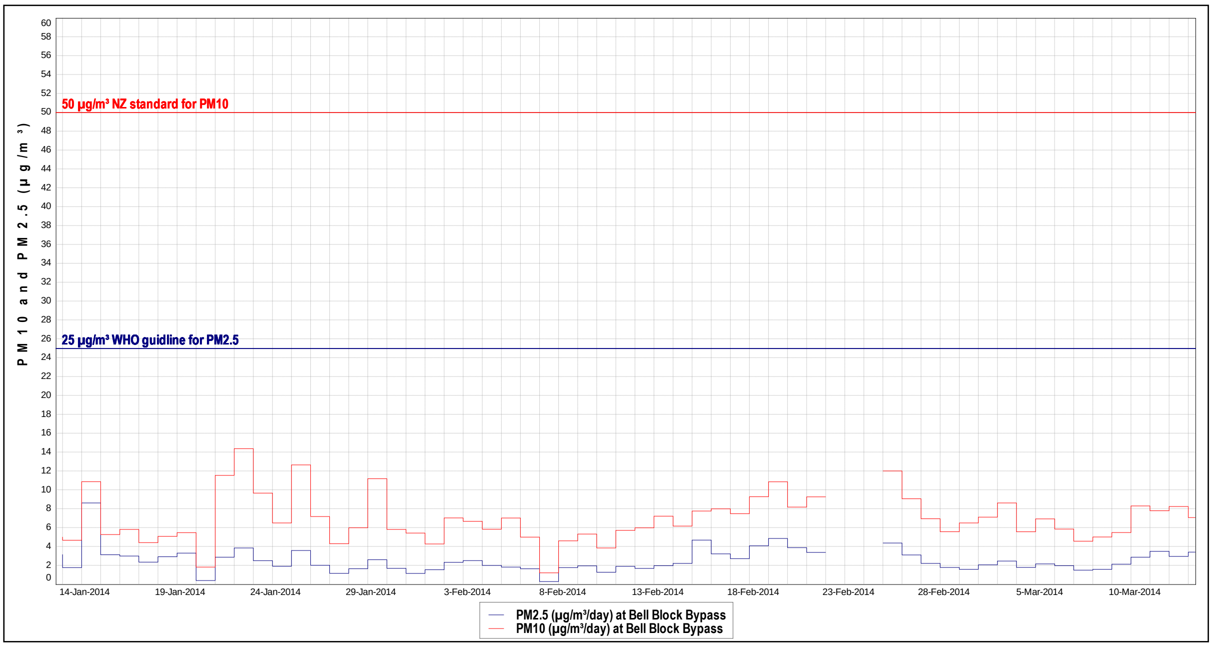

Figure 4 Daily mean PM10 (Red) and PM2.5 (Blue) with criteria at the Bell Block bypass

MfE uses an environmental performance indicator to categorise air quality. These categories are set out in Table 1.

Table 1 Environmental Performance Indicator air quality categories

Measured value	Less than 10% of NES	10-33% of NES	33-66% of NES	66-100% of NES	More than 100% of NES
Category	*excellent*	*good*	*acceptable*	*alert*	*action*

The PM10 results obtained in the current work had an average of 7µg/m³, and the peak value was 14µg/m³ which occurred during a heavy rainfall event. The air quality in the Bell Block Bypass area can be considered as 'excellent' or 'good' for 100 % of the time (Table 2).

Table 2 Categorisation of results - entire dataset

National Environmental Standard for PM10 = 50 µg/m³- 24 hour average.		
Category	Measured values	Days (%)
Excellent	<10% of the NES, (0-5µg/m³)	**18** (30%)
Good	10-33% of the NES, (5-17µg/m³)	**41** (70 %)
Acceptable	33-66% of the NES, (17-33 µg/m³)	**0** (0%)
Alert	66-100% of the NES, (33-50 µg/m³)	**0** (0%)
Total number of days sampled		**59** (100%)

Background levels of PM10 in the region have been found to be around 11µg/m³
The highest daily mean PM 2.5 result for the entire dataset was 9µg/m³. This is equal numerically to 36% of the WHO guideline for PM2.5 of 25µg/m³ (24 hour average).

PM1.0 levels never reached more than a trivial level.

Traffic counts versus PM10/PM2.5 results

TRC has access to a traffic data set provided by the New Zealand Transport Agency. The data was collected on SH3 at Egmont Road. This set covers a forty day period.

Figure 5 presents traffic volumes (15 minutes' total) together with 15 minutes average PM10 results.

The pattern of traffic densities is constant. Three clear peaks in traffic volumes can be observed during week days (morning, midday and afternoon rush hours) with only one midday peak during weekends.

Figure 5 shows that datasets in general have a similarity in diurnal variations. However, from the correlation analysis the association between PM10 and traffic volumes was non-existent, (R^2 = negative). These findings would suggest that there is no relationship between a particular traffic density event and PM 10 values. Visual similarity of diurnal variations between traffic volumes and PM10 concentrations most likely result from the general re-suspension of particles into the air. They may also coincide with higher on-shore breezes during the day and higher traffic flows during daylight hours.

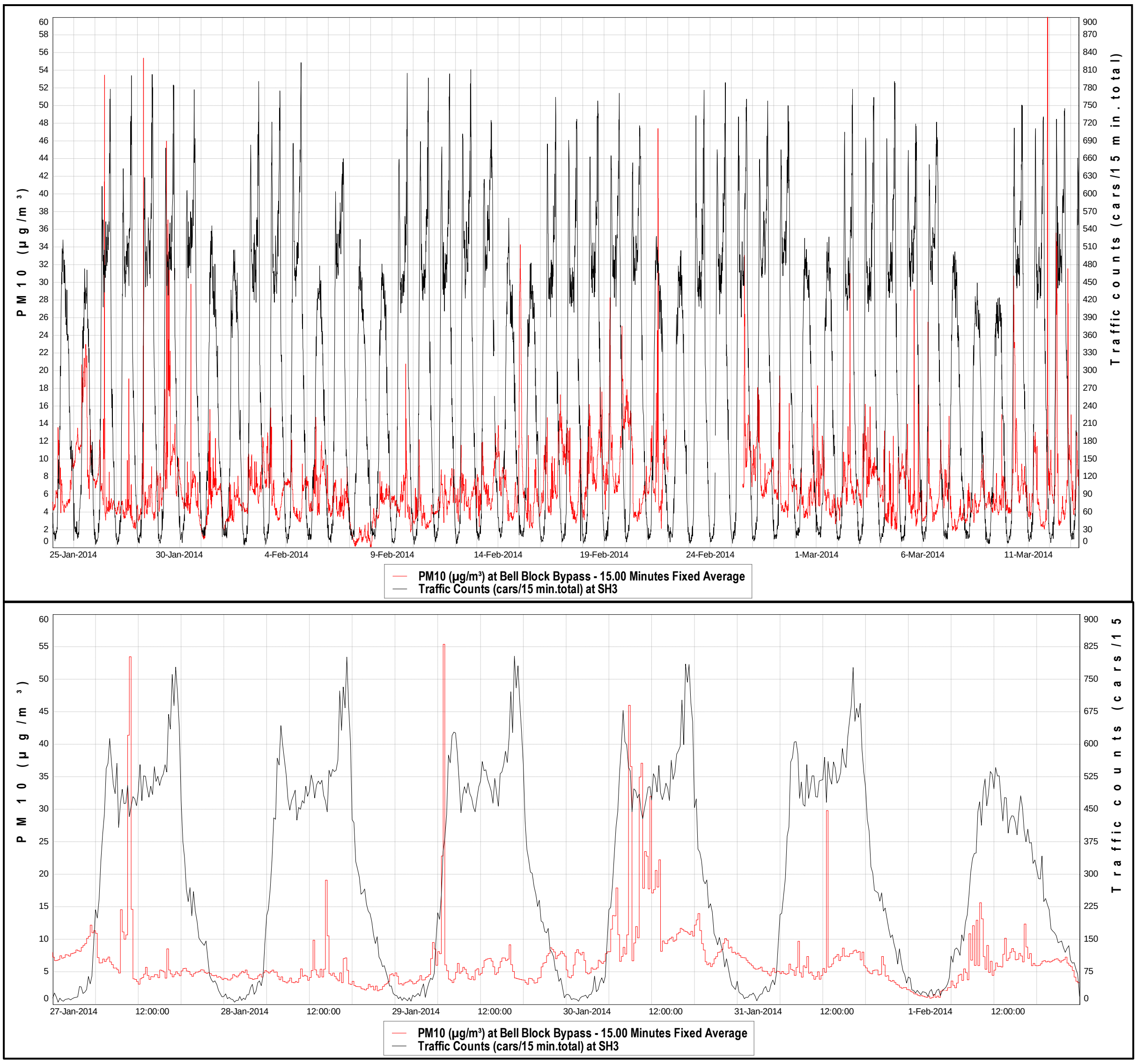

Figure 5 PM10 (15 min. averages) versus traffic counts- entire dataset above with expansion below

Nitrogen Oxides (NOx)

Measurement of nitrogen oxides

The Taranaki Regional Council has been monitoring nitrogen oxides (NOx) in the Taranaki region since 1993 using passive absorption discs. Research to date indicates that this is an accurate method, with benefits of simplicity of use and relatively low cost. To date 496 samplers of nitrogen oxides have been collected in Taranaki region. Discs are sent to EUROFINS ELS Ltd. Lower Hutt for analysis. Passive absorption discs are placed at the nominated sites. The gases diffuse into the discs and any target gases (nitrogen dioxide or others) are captured.

Ambient Nitrogen Oxides (NOx) monitoring was conducted from 5 February to 26 February 2014 at four stationary sites spaced evenly on either sides of the Bell Block over-bridge.

Nitrogen oxides (NOx), a mixture of nitrous oxide (N2O), nitric oxide (NO) and nitrogen dioxide (NO2), are produced from natural sources, motor vehicles and other fuel combustion processes. Indoor domestic appliances (gas stoves, gas or wood heaters) can also be significant sources of nitrogen oxides, particularly in areas that are poorly ventilated. NO and NO2 are of interest because of potential effects on human health.

Nitric oxide is colourless and odourless and is oxidised in the atmosphere to form nitrogen dioxide. Nitrogen dioxide is an odorous, brown, acidic, highly corrosive gas that can affect our health and environment. Nitrogen oxides are critical components of photochemical smog – nitrogen dioxide produces the yellowish-brown colour of the smog.

Environmental and health effects of nitrogen oxides

Nitrogen dioxide is harmful to vegetation, can fade and discolour fabrics, reduce visibility, and react with surfaces and furnishings. Vegetation exposure to high levels of nitrogen dioxide can be identified by damage to foliage, decreased growth or reduced crop yield.

Nitric oxide does not significantly affect human health. On the other hand, elevated levels of nitrogen dioxide cause damage to the mechanisms that protect the human respiratory tract and can increase a person's susceptibility to, and the severity of, respiratory infections and asthma. Long-term exposure to high levels of nitrogen dioxide can cause chronic lung disease. It may also affect sensory perception, for example, by reducing a person's ability to smell an odour.

National Environmental Standards and guidelines

In 2004, National Environmental Standards (NES) for ambient (outdoor) air quality were introduced in New Zealand to provide a guaranteed level of protection for the health of New Zealanders. The national standard for the nitrogen dioxide (NO2) is set out below.

In any 1-hour period, the average concentration of nitrogen dioxide in the air should not be more than 200 $\mu g/m^3$.

Before the introduction of the NES, air quality was measured against the national air quality guidelines. The national guidelines were developed in 1994 and revised in 2002 following a comprehensive review of international and national research and remain relevant. The national guideline for the nitrogen dioxide (NO2) is set out below.

In any 24-hour period, the average concentration of nitrogen dioxide in the air should not be more than 100 $\mu g/m^3$.

Conversion of exposure result to standardised exposure time period

From the average concentration measured, it is possible to calculate a theoretical maximum daily or one hour concentrations that may have occurred during the exposure period. Council data on NOx is gathered over a time period other than exactly 24 hours or one hour. There are mathematical equations used by air quality scientists to predict the maximum concentrations over varying time periods. These are somewhat empirical, in that they take little account of local topography, micro-climates, diurnal variation, etc. Nevertheless, they are applied conservatively and have some recognition of validity.

One formula in general use is of the form:

$$C(t_2) = C(t_1) \times \left(\frac{t_1}{t_2}\right)^P$$

where C(t) = the average concentration during the time interval t, and p = a factor lying between 0.17 and 0.20. When converting from longer time periods to shorter time periods, using p = 0.20 gives the most conservative estimate (i.e. the highest calculated result for time period t_2 given a measured concentration for time period t_1). Using the 'worst case' factor of p = 0.20, the monitoring data reported above has been converted to equivalent 'maximum' 1-hour and 'maximum'24-hour exposure levels.

Results

Table 3 presents the actual levels found and theoretical maximum daily and hourly concentration of NOx.

Table 3 Actual (laboratory) and recalculated ambient NOx results, NES and MfE guideline.

Site code	Site description	NOx (µg/m³) Lab. results	NOx/1hr (µg/m³) (Theoretical maximum)	NOx/24hr (µg/m³) (Theoretical maximum)
AIR000046	NW of the bridge	7.2	25.0	13.2
AIR000047	NE of the bridge	8.0	28.0	14.7
AIR000048	SE of the bridge	8.6	30.0	16.0
AIR000049	SW of the bridge	9.2	32.0	17.0
National Environmental Standard (NES)* and MfE guideline**			**200***	**100****

Discussion

The calculated 1-hour and 24-hour theoretical maximum concentrations (using a power law exponent of 0.2) for the four monitoring sites are similar and ranged from 25.0 µg/m³ to 32.0 µg/m³ and 13.2 µg/m³ to 17.0 µg/m³ respectively. Comparable results have been found in other studies previously at sites beside major highways in Taranaki region. All values found in this study were within the NES and Ministry for the Environment Ambient Air Quality Guidelines being about 15% of both limits. The monitoring showed that 100% of the 1-hour average results fell into Ministry's 'good' category (and are just outside the 'excellent' category). This continues the pattern found in previous years at other sites.

BTEX

Introduction

Volatile organic compounds (VOCs) can have a significant effect on air quality. They are emitted into the atmosphere from controlled as well as from non-controlled sources. Due to high volatility and high vapour pressure, they are predominant in the atmosphere. They can be transported to areas far away from emission sources and increase risk to human health. The common occurrence and properties make this a risk to populations that are exposed to VOCs. The most abundant pollutants among the VOCs emitted into the atmosphere are monoaromatic hydrocarbons: benzene, toluene, ethylbenzene, and xylenes (BTEX), which are also markers for human exposure to VOCs. Exposure of the population to benzene and other VOCs has been the subject of much interest in the scientific community due to the toxicity of these compounds.

BTEX monitoring was conducted from 5 February to 26 February 2014 at four stationary sites spaced evenly on either sides of the Bell Block over-bridge using a passive sampling method.

The findings of this study are presented in this memorandum.

The Council has previously undertaken BTEX monitoring in March 2003 around a petrol station in New Plymouth, in March 2005 around two large gas production stations, and in April 2012 at four monitoring sites throughout the region.

Benzene

Benzene occurs naturally in fossil fuels and is produced in the course of natural processes and human activities that involve the combustion of organic matter such as wood, coal and petroleum products. Natural sources of benzene emissions to the atmosphere are estimated in order of 3-5% while more than 90% are estimated to come from anthropogenic sources (gasoline vapours, vehicle exhaust, and chemical production).

Toluene

Toluene occurs naturally as a component of crude oil and is a major aromatic constituent of petrol which contains about 5-7% toluene by weight. It is produced in the process of making gasoline and other fuels from crude oil, in making coke from coal, and as by-product in the manufacture of styrene. It is used as an intermediate in the manufacture of many end products. Toluene is also used in a mixture added to gasoline to improve octane ratings. Toluene is released into the atmosphere principally from the volatilization of petroleum fuels, from motor vehicle exhaust and from toluene-based solvents and thinners with the largest sources of release the production, transport, and use of gasoline.

Ethylbenzene

Ethylbenzene is naturally present in crude petroleum. It is also a by-product of biomass combustion. Ethylbenzene is almost exclusively (>99%) used as an intermediate for the manufacture of styrene monomer. Ethylbenzene will enter the atmosphere primarily from fugitive emissions during the use of fuel and solvents (which account for the bulk of emissions) and exhaust connected with its use in gasoline.

Xylenes

Xylenes exist in ambient air as a mixture of ortho (o-), meta (m-) and para (p-) isomers (the term “xylenes” refers to all three isomers). Xylenes are primarily synthetic chemicals produced from petroleum but also occur naturally in petroleum and coal tar.

In this study concentrations of o-, p-, and m-xylene were summed and reported as xylene total. Xylenes are released to the atmosphere primarily as fugitive emissions from industrial sources (e.g., petrochemical and chemical plants), in automobile exhaust, and through volatilization from there use as solvents.

The term BTEX reflects that benzene, toluene, ethylbenzene and xylenes are often found together.

Health effects

Exposure to BTEX can occur by ingestion (consuming water contaminated with BTEX), inhalation (exposure to BTEX present in the air) or absorption through the skin. Inhalation of BTEX can occur while pumping gasoline. Absorption of these chemicals can occur by spilling gasoline onto one's skin. Acute exposures to high levels of gasoline and its BTEX components have been associated with skin and sensory irritation, central nervous system depression, and effects on the respiratory system. These levels are not likely to be achievable from drinking contaminated water, but are more likely from occupational exposures. Prolonged exposure to these compounds has effects on the kidney, liver and blood systems. According to the United States Environmental Protection Agency (USEPA), there is sufficient evidence from both human and animal studies to determine that benzene is a human carcinogen. Workers exposed to high levels of benzene in occupational settings were found to have an increased incidence of leukaemia.

Summary of method

Passive absorption samplers that absorb the target gas into activated carbon and are subsequently analysed using gas chromatography, are employed to collect target constituents. The measurement of recovered constituents allows determination of the average concentration of the gas in the air during the time of exposure. BTEX concentration is reported as µg/m³ (mass of BTEX per volume of air). The laboratory analysis includes a step of measuring the quantity of BTEX compounds collected on the passive badges, and converting this to an equivalent ambient concentration. When analysis of the field blank shows the presence of BTEX compounds, it is appropriate to consider subtracting this blank result from the quantities detected on the remaining samples, before calculating causal ambient concentrations. In this survey, the amounts of TEX detected were comparatively very small or non-detectable by comparison with the amounts on the deployed samplers, and so results for toluene, ethyl benzene, and xylene have not been adjusted. On the other hand, the amount of benzene detected in the blank analysis was equivalent to up to 30% of that in the field samples, and so adjusted figures have been added to Table 4. Unadjusted results give the maximum concentration that could have been present; results adjusted for blank corrections will give a result closer to the more likely 'actual' result. In Table 4 below, the adjusted results are shown alongside the uncorrected results. A conservative approach will be to consider the 'actual' concentration lies between the two figures. *(Text added in January 2019)*

Guidelines

In New Zealand, benzene is the only member of the BTEX group subject to a national guideline value. The Ministry for the Environment guideline, based on benzene's known mutagenic and carcinogenic properties, was 10µg/ m3 as an annual average, reduced to 3.6µg/m3 in 2010. There are no national ambient air quality guidelines for toluene, ethylbenzene or xylene. The Ministry for the Environment had prepared an internal technical document "Health Effects of Eleven Hazardous Air Contaminants and Recommended Evaluation Criteria" (October 2000) that suggested a 1 hour average value of 22 µg/m3 for Benzene, 500 µg/m3 for Toluene and 1000 µg/m3 for Xylene as recommended guidelines values. However, these recommendations were not carried through to the final Ministry for the Environment guidelines published in 2002.

Results

Conversion of exposure result to standardised exposure time period

The same conversion process for standardising of BTEX exposure period has been used as described for NOx above.

Using the 'worst case' factor of p = 0.20, the monitoring data reported herein have also been converted to equivalent 'maximum' one hour exposure levels (Table 4).

Table 4 Actual and recalculated (p0.2) BTEX results at Bell Block Bypass

Site	Site ID	Where	Time total Hrs	Benzene			Toluene		Ethyl Benzene	o,m,p – Xylene Total	
				Lab. Results	1 hr. Calc^{1}.	1 hr. Calc^{2}.	Lab. Results	1 hr. Calc.	Lab. Results	Lab. Results	1 hr. Calc.
1	AIR000046	NW	506	0.32	1.12	0.75	1.24	4.34	0.4	1.1	3.85
2	AIR000047	NE	506	0.65	2.28	1.92	2.0	7.0	0.54	1.52	5.32
3	AIR000048	SE	506	0.64	2.24	1.86	1.5	5.25	2.8	1.52	5.32
4	AIR000049	SW	506	0.33	1.16	0.79	0.31	1.09	3.1	1.85	6.48
MfE recommended **guidelines** (2000), one -hour average.					**22**			**500**			**1000**

* All results in µg/m³ Calc^{1} 1-hour average ambient concentration, no blank correction
Calc^{2} 1-hour average ambient concentration adjusted for blank recovery (*This data added in January 2019)*

Discussion

The calculated 1-hour theoretical maximum concentrations of benzene (using a power law exponent of 0.2) ranged from 1.12 µg/m³ or less, to 2.28 µg/m³. The results from monitoring of toluene, ethylbenzene and xylene have all been extremely low. All values were far below the Ministry for the Environment recommended guidelines (2000). This continues the pattern found in previous years.

Environmental Performance Indicator

Ministry for the Environment uses an environmental performance indicator to categorise air quality. These categories are set out in Table 5 and further details of the BTEX results are set out in Table 6.

Table 5 Environmental Performance Indicator air quality categories

Measured value	Less than 10% of guideline	10-33% of guideline	33-66% of guideline	66-100% of guideline	More than 100% of guideline
Category	*excellent*	*good*	*acceptable*	*alert*	*action*

Table 6 Categorisation of results - Benzene (2012)

MfE guideline (2000) Benzene = 22 µg/m³- 1 hour average.		
Category	**Measured values**	
Excellent	<10% of the guideline, (0-2.2µg/m³)	**2** (50%) **4** (100%) if using adjusted values
Good	10-33% of the guideline, (2.2-7.3µg/m³)	**2** (50 %) 0 if using adjusted values
Acceptable	33-66% of the guideline, (7.3-14.5 µg/m³)	**0** (0%)
Alert	66-100% of the guideline, (14.5-22 µg/m³)	**0** (0%)
Total number of samples		**4** (100%)

The levels of Toluene and Xylene obtained in the current work are far below ambient guideline values, and all results fall into 'excellent' Ministry's air quality category. Two of the four benzene results were within 'excellent' MfE's category and two results fell within the 'good' category.

Conclusion

The results of this study at Bell Block Bypass and all regional monitoring to date, have shown that Taranaki has very clean air and on a regional basis there are no significant pressure upon the quality of the air resource.