Community monitoring report

Lead and arsenic in air near Exide Technologies Ltd, Petone (March to June 2009)

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Tamsin Mitchell
Environmental Monitoring and Investigations Department

For more information, contact:

Greater Wellington
142 Wakefield Street
PO Box 11646
Manners Street
Wellington 6142
T 04 384 5708
F 04 385 6960
www.gw.govt.nz

GW/EMI-G-09/277

ENV/06/06/11

October 2009

Executive summary

Ambient air quality monitoring for lead and arsenic was undertaken near Exide Technologies Limited's (Exide) battery recycling plant in Petone, Lower Hutt, from 1 March to 5 July 2009. Total suspended particulate in air was sampled continuously for 24-hour periods every second day using a high-volume sampler at two monitoring sites in the community: a commercial site on Waione Street and a residential site on Kirkcaldy Street. This study repeats the monitoring undertaken in 1999. Monitoring undertaken in 2008 was thought not to adequately represent air quality due to periods of abnormal operation at Exide.

Key findings:

- Concentrations of lead in air measured in the community are less than the new US Environmental Protection Agency standard for lead in air. The US standard was lowered from 1.5 to 0.15 µg/m^3 in October 2008.

- The rates of deposited lead reported by Exide for both community sites in 2009 are lower than what was reported in 2003 and 2004.

- The average concentration of lead in air at measured at Waione Street is at least 60% lower than what was measured in 1999.

- The average concentration of lead in air measured at Kirkcaldy Street is at least 43% lower than what was measured in 1999.

Contents

1. Introduction and background

Levels of lead in air at community monitoring sites in Petone, Lower Hutt, were first monitored in 1999 (Davy 1999). The results of the 1999 study were used in the Air and Environmental Sciences (AES) health-risk assessment model commissioned by Regional Public Health during the 2005 statutory review of Exide Technologies Ltd's (Exide) discharge to air resource consent conditions. The community monitoring was repeated in 2008 (Mitchell 2008), to gain more up-to-date information about levels of lead in air, at the request of Greater Wellington's Environmental Regulation Department. However, the 2008 monitoring results were not considered to be 'representative' as the monitoring coincided with major maintenance work and a period of plant shutdown at Exide.

This 2009 study replicates the monitoring carried out in 1999 and 2008. The 2009 monitoring programme commenced shortly after Exide installed a new baghouse designed to reduce emissions from the 37 m high furnace bag filter stack.

1.1 Exide discharges and fugitive emissions limits

Exide operates a secondary lead smelter in Petone where used lead-acid batteries and scrap lead are refined to produce pure lead or lead alloys. The furnace waste (slag) is processed on-site and after stabilisation is transported off-site for storage and subsequent landfilling.

All discharges to air from the site are authorised by resource consent WGN000128 [24363]. Mass emission limits for a range of contaminants, including lead and arsenic, apply to discharges from the 37 m high furnace bag filter stack and the 12 m high cartridge dust collector vent.

Emission limits for fugitive discharges of lead from the yard and processing facilities were imposed as one of the outcomes of the 2005 review of Exide's resource consent conditions. The following limits (3-month moving average, based on 6-day averages) apply to three of Exide's site boundaries:

- 1.5 µg/m^3 on the southern boundary
- 0.8 µg/m^3 on the northern boundary
- 0.55 µg/m^3 on the western boundary

As a further condition of their resource consent, Exide undertake deposition monitoring for lead and arsenic in deposited particulate on the southern, northern and western site boundaries, and at Waione Street, Kirkcaldy Street and Unilever.

2. Contaminants investigated

2.1 Total suspended particulate (TSP)

Total suspended particulate (TSP) measured using a high-volume sampler includes airborne particles with an equivalent aerodynamic diameter of less than 50 µm. These particles are produced from combustion, industrial processes, motor vehicles, burning and natural sources such as wind-blown dust and sea salt. Particles 10 µm or less in aerodynamic diameter (PM_{10}) may be inhaled and are known to cause a range of adverse health effects. While a national standard for PM_{10} exists, there is no New Zealand health-based guideline for TSP which has predominantly nuisance or amenity effects such as soiling. In this study, TSP is sampled in order to also capture the larger-sized lead particles (above 10 µm) that may be present in airborne dust.

2.2 Lead in air

The concentration of lead in air can be calculated from the mass of lead collected in a known volume of air. The principal source of lead in air in the study area is discharges from Exide. Other potential sources of lead in the environment include dust from lead-based paint removed during renovations. Because lead is an environmentally persistent contaminant, there may be lead in soils or dust deposited from lead-smelting and refining activities and from vehicle emissions prior to the completed phase out of leaded petrol in 1996. A small fraction of this 'historical' lead may re-enter the air due to the action of wind or when soils are exposed.

Adverse health effects of lead are related to increases in the concentration of lead in blood following ingestion of deposited particulate and/or inhalation of particulate or lead fume. The national ambient air quality guideline (MfE 2002) for lead of 0.2 $\mu g/m^3$ (3-month moving average), based on 24-hour averages, is designed to protect against adverse health effects from inhalation exposure. This guideline relates only to the particulate assessed as PM_{10}. TSP was dropped as a measurement method for lead in particulate in 1994 in recognition that PM_{10} monitoring was more commonplace due to the existence of a PM_{10} guideline (MfE 1994).

In November 2008, the US EPA standard for lead in air was revised downwards from 1.5 $\mu g/m^3$ (averaged over a calendar quarter) to 0.15 $\mu g/m^3$ (three-month rolling average). The standard is assessed as TSP so that the contribution of any ultra-coarse lead particulate is included. Compliance with the standard is achieved when there are no exceedences of 0.15 $\mu g/m^3$ within a consecutive three year period.

2.3 Arsenic in air

As with lead, the concentration of arsenic in air can be calculated from the mass of arsenic collected in a known volume of air. Non-industrial sources of arsenic in air include domestic burning of timber treated with copper-chrome-arsenic preservative (CCA). Arsenic is classified as a carcinogen by the International Agency for Research on Cancer (IARC) and the US

Environmental Protection Agency. The current national guideline (MfE 2002) for arsenic is 0.0055 µg/m^3 (annual average) measured as PM_{10}.

2.4 Deposited lead dust

Dust fallout is the combined rate of dust deposited under wet and dry conditions. It is typically measured by exposing a vessel (gauge) with a standard surface area for a specified time period. Typically these gauges collect dust particles greater than 10-20 µm (MfE 2001), with results expressed as mass per area per exposure time.

The quantity of lead in deposited dust can be used as an input to multi-pathway exposure models for determining human health risks. However, it should be noted that the deposition is a surrogate surface and lead particulate will deposit at different rates depending on the surface (e.g., vegetation, bare soils, paved etc.). Deposition gauges are a relatively unsophisticated monitoring method and can show considerable variability in results. They are, therefore, best suited for establishing long term trends rather than spot measurements for compliance assessment.

There are no standards or guidelines for lead in deposited particulate. The MfE ambient air guidelines (MfE 2002) note that where there is the likelihood of ingestion from deposited lead, this exposure pathway must be taken into account (in addition to inhalation exposure) when assessing health impacts on children.

3. Monitoring sites and methods

3.1 Monitoring sites

Two high-volume samplers were deployed over March to June 2009 in the same locations as in 1999 and in 2008 (Figure 3.1). Photos of the high-volume samplers are shown in Figures 3.2 and 3.3.

Figure 3.1: Map showing location of ambient air monitors and deposition gauges

Figure 3.2: Kirkcaldy Street high-volume sampler

Figure 3.3: Waione Street high-volume sampler

3.2 Methods

3.2.1 Ambient air sampling

Two high-volume samplers (Lear Siegler flow-set) fitted with TSP heads were operated in accordance with AS/NZ 3580.9.3:2003 on a one-in-two day sampling regime from midnight to midnight.

Ambient air was drawn (70 m^3/hour) through pre-conditioned and pre-weighed filters (Whatman EPM 2000). After 24-hour exposure the filters were removed, re-conditioned and reweighed. The results are expressed as TSP 24-hour average in µg/m^3 corrected to standard conditions (0^oC and 101.3 kPa). The full record of monitoring results is presented in Appendix 1.

3.2.2 Analytical methods

Gravimetric and chemical analyses of the filter media were carried out by Environmental Laboratory Services (ELS), Seaview, Lower Hutt. Exposed filters were quartered before undergoing hot acid digestion based on AS 2800-1985. Lead and arsenic content were determined by ICP-MS (inductively coupled plasma – mass spectroscopy).

The analytical detection limit for arsenic reported by ELS was 0.8 µg per filter. For data analysis purposes filter weights reported as less than 0.8 µg were replaced by values one half of this detection limit (i.e., 0.4 µg prior to being converted to µg/m^3).

3.2.3 Quality assurance

Both high-volume samplers were calibrated using a variable orifice flow calibrator on 18 February 2009 before sampling began and on 30 March 2009, 1 May 2009, 2 June 2009 and subsequently on 16 July 2009 once the sampling programme was completed. The calibrations confirmed that the instruments were operating within acceptable limits and only minor corrections were made to the flow rates used to calculate the final contaminant concentrations. Field and laboratory blanks were included in the analyses for quality assurance purposes, with blank filter concentrations taken into account when calculating the final concentrations.

3.2.4 Statistical analysis

The data analyses used in this report were undertaken using the statistical package R version 2.9.1 (R Development Core Team 2009).

The non-parametric Wilcoxon rank sum test (equivalent to the Mann-Whitney U-test) and the parametric Welch two sample *t*-test were used to evaluate the differences between lead, arsenic and TSP concentrations measured at the two monitoring sites and the difference in lead concentrations between 1999 and 2009.

Comparative box plots have been used in this report to display monitoring results as shown in Figure 3.4.

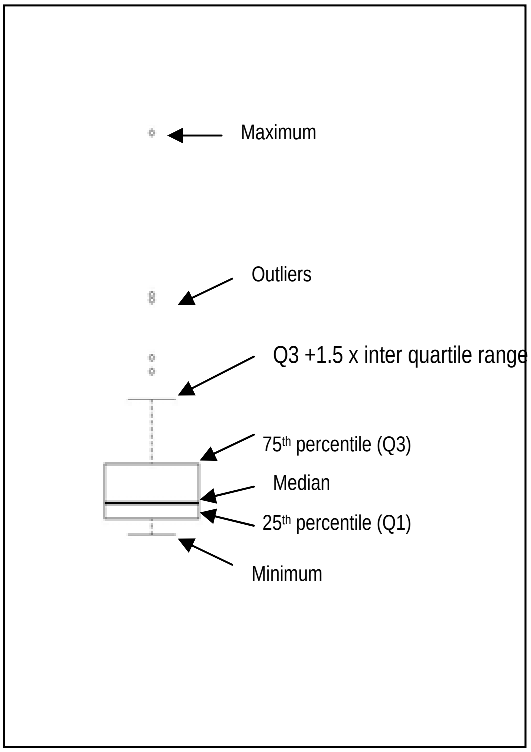

Figure 3.4: Interpretation of box plots

4. Ambient air quality - results and discussion

4.1 Meteorology

Meteorological data are available from Shandon Golf Course, approximately 750 m north-east of the community monitoring sites. A wind rose for the monitoring period is presented in Appendix 2. During the monitoring period the wind was northerly to north-easterly 43% and southerly 24% of the time.

4.2 Total suspended particulate (TSP)

TSP monitoring results are presented in Tables A1.1 and A1.2 of Appendix 1, with summary statistics given in Table A3.1 of Appendix 3. The 24-hour average TSP concentrations measured at Waione Street and Kirkcaldy Street are shown in Figure 4.1. The levels of TSP measured at both sites are typical of a coastal urban area, located near a busy road and close to industrial and commercial premises with a significant contribution from sea salt and soil-derived matter.

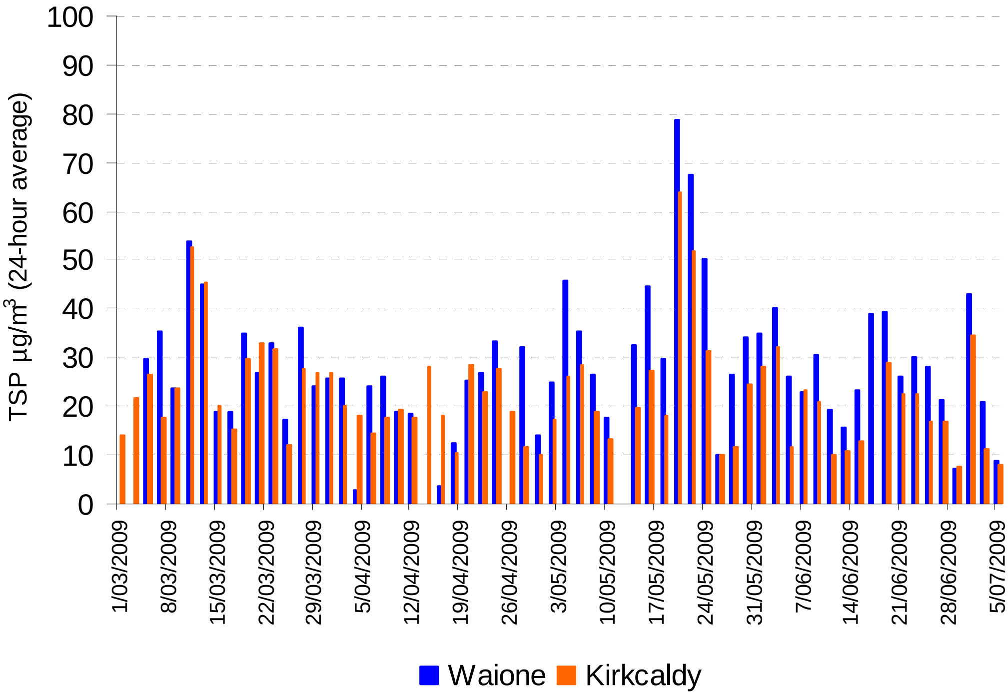

Figure 4.1: Time series of TSP concentrations (1 March to 5 July 2009)

4.3 Lead in air

Lead monitoring results are presented in Tables A1.1 and A1.2 of Appendix 1, with summary statistics given in Table A3.2 of Appendix 3. The 24-hour average lead concentrations measured at Waione Street and Kirkcaldy Street are shown in Figure 4.2. Monthly averages and three-month rolling averages are presented in Table 4.1. The three month averages compare favourably with the US EPA standard of 0.15 µg/m^3 (3-month moving average). During the monitoring period the average lead in air concentration measured by Exide at their southern boundary was 0.15 µg/m^3 (average of 6-day filter exposure results).

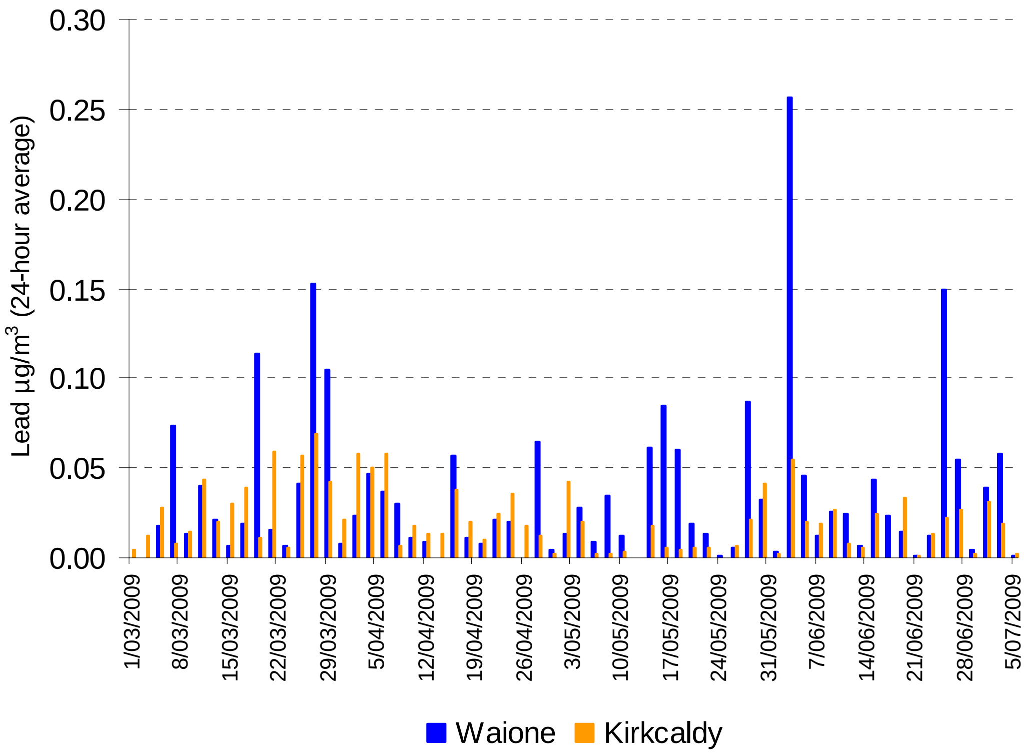

Figure 4.2: Time series of lead concentrations (1 March to 5 July 2009)

Table 4.1: Monthly and three-monthly average lead concentrations

Lead (µg/m^3) in TSP	Waione Street	Kirkcaldy Street	Averaging time
March 2009	0.045	0.029	1-month
April 2009	0.026	0.025	1-month
May 2009	0.033	0.013	1-month
June 2009	0.045	0.018	1-month
March, April, May 2009	0.035	0.022	3-month
April, May, June 2009	0.035	0.019	3-month moving

4.4 Arsenic in air

Arsenic monitoring results are presented in Tables A1.1 and A1.2 of Appendix 1, with summary statistics given in Table A3.3 of Appendix 3. Figure 4.3 shows the 24-hour average arsenic concentrations measured at Waione Street and Kirkcaldy Street. Eight samples from each monitoring site were below the laboratory level of detection for arsenic.

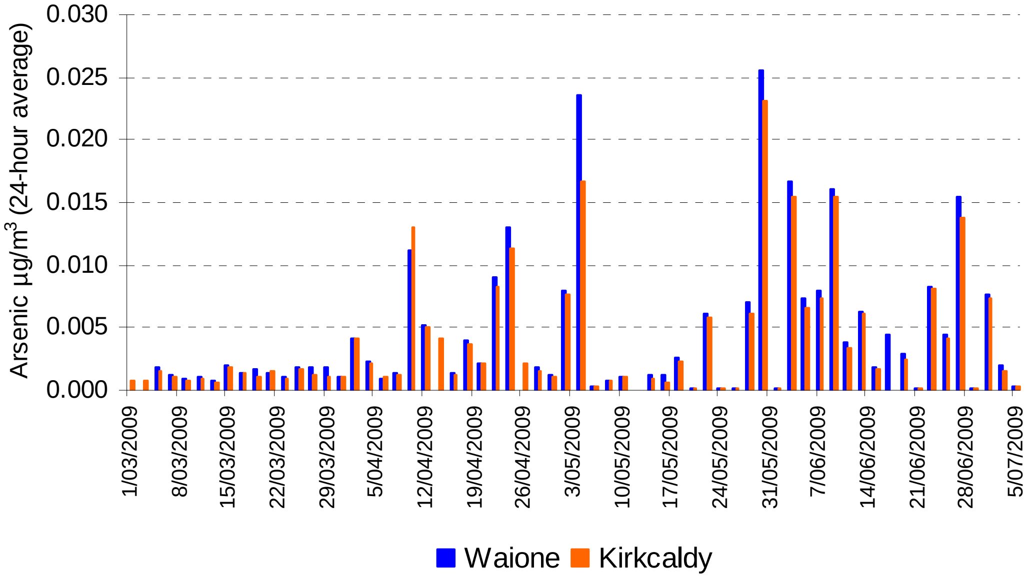

Figure 4.3: Time series of arsenic concentrations (1 March to 5 July 2009)

As observed in 2008, peak concentrations of arsenic appear to occur during the winter months, possibly due to the additional contribution of another arsenic source such as domestic burning of CCA-treated timber. Increases in arsenic concentrations during the winter months due to domestic burning of CCA-treated timber have been found elsewhere in the Wellington region, for example in Wainuiomata (Davy et al. 2009). A longer period of monitoring and other investigations (e.g., receptor modelling) would be required in order to confirm whether domestic fires are a local source of arsenic during the winter months.

4.5 Comparison of monitoring results between sites

Average and median TSP concentrations were higher at Waione Street than those measured at Kirkcaldy Street. The differences are statistically significant at the 95% confidence level. The average TSP concentration at Waione Street is at least 2.40 µg/m^3 higher than that measured at Kirkcaldy Street.

The average lead concentration measured at Waione Street is only slightly higher (at least 0.006 µg/m^3) than that measured at Kirkcaldy Street. The difference in median lead concentration between the two sites is not statistically significant at the 95% confidence level.

Average and median concentrations of arsenic measured at both sites are not statistically different at the 95% confidence level.

Figure 4.4 shows comparative box plots of the monitoring results.

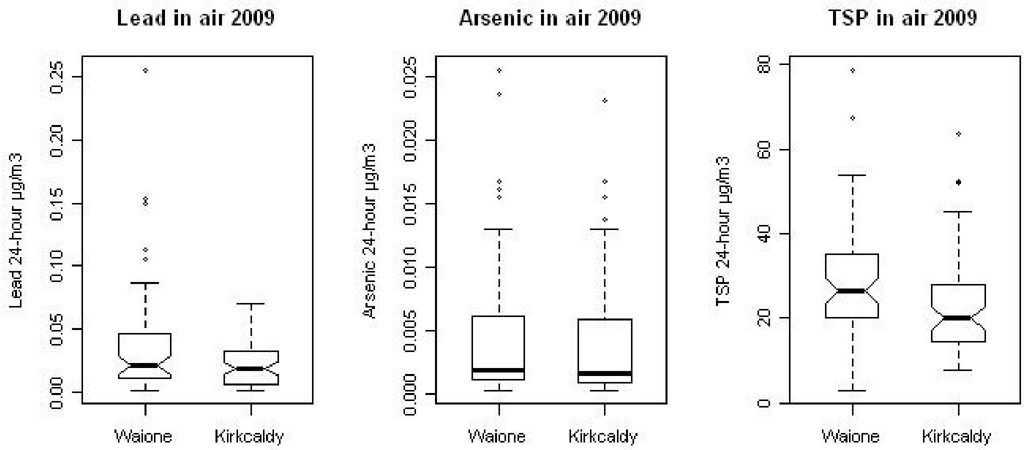

Figure 4.4: Box plots of 24-hour concentrations measured at each site in 2009

4.6 Comparison of 2009 with 1999 monitoring results

Figure 4.5 compares the average monthly concentrations of lead measured at both sites in 1999 and in 2009.

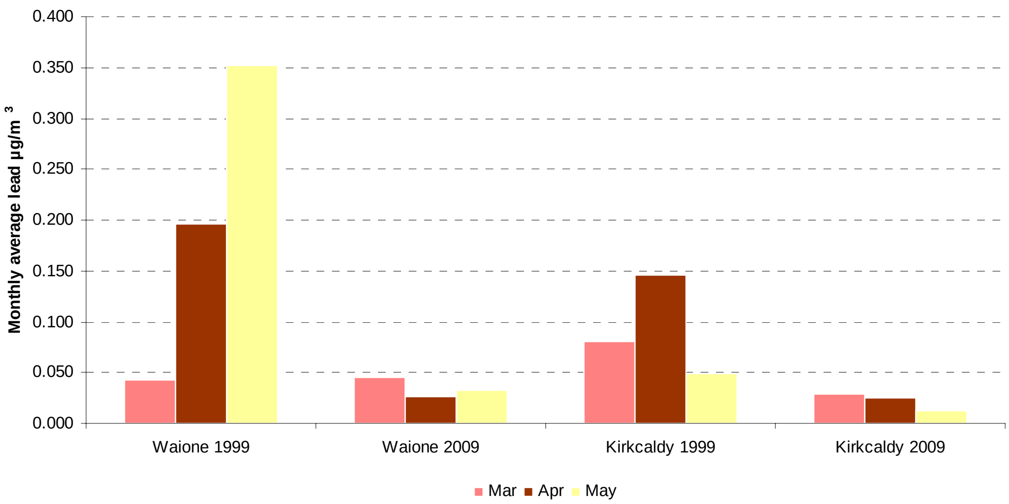

Figure 4.5: Monthly average lead concentrations at Waione Street and Kirkcaldy streets in 1999 and 2009

Table A3.4 in Appendix 3 provides summary statistics for 1999 measurements of lead in air. In 2009 median and average lead and TSP concentrations at both sites are lower than those measured in 1999. The difference between the means is statistically significant at the 95% confidence level.

At Waione Street, the average lead concentration of 0.037 µg/m^3 is at least 0.19 µg/m^3 lower than the 1999 average of 0.31 µg/m^3 (the lower bound of the 95% confidence interval of the difference between the two means). Likewise, average concentration of 0.022 µg/m^3 measured at Kirkcaldy Street is at least 0.04 µg/m^3 lower than the 1999 average of 0.10 µg/m^3 (the lower bound of the 95% confidence interval of the difference between the two means).

Figure 4.6 compares the distribution of lead and TSP concentrations measured at Waione Street and Kirkcaldy streets during the 1999 and 2009 monitoring campaigns.

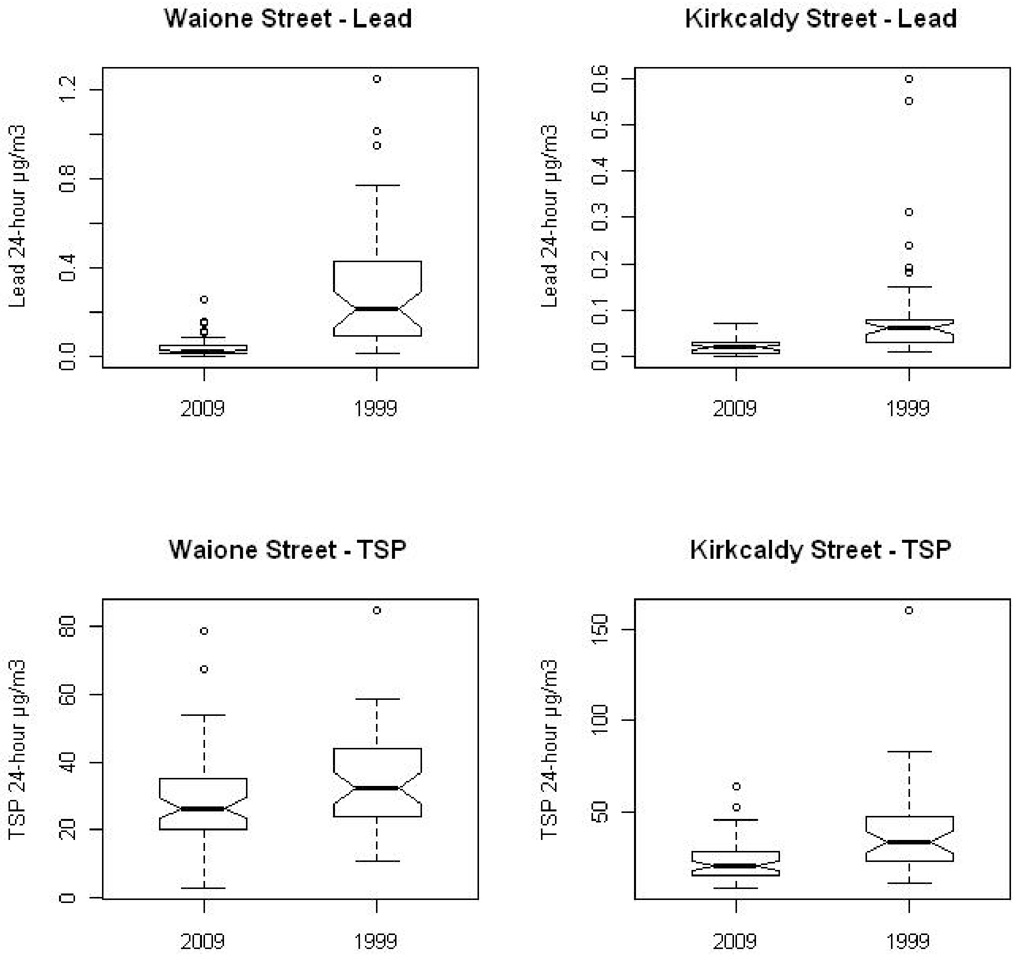

Figure 4.6: Box plots of lead and TSP concentrations measured at Waione Street and Kirkcaldy streets in 2009 and 1999

5. Deposition monitoring – results and discussion

5.1 Lead deposition rates

Rates of deposited lead measured by Exide's deposition gauges at Kirkcaldy Street and Waione Street are presented in Table 5.1.

Table 5.1: Lead deposition rates at Waione Street and Kirkcaldy Street

2009	Lead mg/m^2/month	
Month	Kirkcaldy St	Waione St
March	2.84	6.10
April	2.71	5.21
May	1.30	6.35
June	1.10	1.82
Average	1.99	4.87

5.2 Lead deposition velocities

Deposition velocity is the rate at which particles are deposited on a surface from a reference height, reported in cm/second. The mass of depositing particles is the most important factor affecting deposition velocities (i.e., larger and heavier particles fall faster and are deposited closer to the emission source).

Estimated deposition velocities for lead particles in the vicinity of Exide were one of the critical inputs to the health risk assessment modelling undertaken by Air and Environmental Sciences Ltd (AES) for Regional Public Health (RPH). The AES model was used to determine lead concentration limits at Exide's site boundary that would protect public health. It was noted in the Environment Court decision (W09/2006) on the appeal of Greater Wellington's decision on the review of Exide's resource consent, that updated information on deposition velocities would be needed to confirm that the site boundary emission limits had been set appropriately.

In 2005, deposition velocities for both Kirkcaldy Street and Waione Street were estimated by dividing average deposition rates for 2003 and 2004 by average ambient concentrations in 1999 (Stevenson 2005). Deposition rates measured by Exide in 2009 are much lower than those measured in 2003 and 2004. Consequently, the re-calculated deposition velocities are also lower, particularly at Waione Street.

Table 5.2 shows the deposition velocities used in the 2005 AES model commissioned by RPH and the 2009 deposition velocities calculated from co-located measurements of deposition rates and ambient air concentrations at Kirkcaldy Street and Waione Street.

Table 5.2: Estimated deposition velocities (cm/s) obtained from co-located measurements of deposition rates and ambient air concentrations

Deposition velocities	2005(AES model estimates)		2009 (updated estimates)		
	Min	Max	Min	Max	Average
Waione St	12	12	1.5	7.5	4.9
Kirkcaldy St	2	5	2.1	4.0	3.5

The average estimated lead deposition velocities of 4.9 cm/s at Waione Street and of 3.5 cm/s at Kirkcaldy Street are lower than the values of 12 cm/s and 5 cm/s estimated for these sites in 2005. This finding suggests that the lower rate of lead deposition in 2009 (compared to before 2005) provides a greater level of health protection than was estimated by the 2005 health risk assessment model commissioned by Regional Public Health.

6. Conclusion

Ambient air quality monitoring to the west of Exide at Kirkcaldy Street during March to June 2009 found lead concentrations of 0.022 µg/m^3 (3-month average) and 0.019 µg/m^3 (3-month moving average). To the south of Exide at Waione Street during the same period concentrations of 0.035 µg/m^3 (3-month average) and 0.035 µg/m^3 (3-month moving average) were found. These results compare favourably with the revised US EPA standard of 0.15 µg/m^3 for lead in air.

Average arsenic concentrations measured at both sites in 2009 were very similar: 0.0040 µg/m^3 at Waione Street and 0.0039 µg/m^3 at Kirkcaldy Street. There may be a seasonal component to arsenic concentrations, with peaks being observed during the winter months, possibly due an additional source of arsenic in air related to the domestic burning of CCA-treated timber.

The average concentration of lead in air measured at Waione Street is at least 60% lower than that measured in 1999. The average concentration of lead in air measured at Kirkcaldy Street is at least 43% lower than that measured in 1999.

The average estimated lead deposition velocities of 4.9 cm/s at Waione Street and of 3.5 cm/s at Kirkcaldy Street are lower than the values of 12 cm/s and 5 cm/s estimated for these sites in 2005. This finding suggests that the lower rate of lead deposition in 2009 (compared to before 2005) may provide a greater level of health protection in Waione Street than was estimated by the 2005 AES health risk assessment model commissioned by Regional Public Health.

7. References

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Acknowledgements

Thank you to Darren Li for installing and calibrating the high-volume samplers. We would also like to thank BBR Contech for access to their site and power supply, Mr Johnson for allowing a monitor to be sited on his property and Universal Trucks for allowing their site to be used. We are also grateful to Donna Rowan of Environment Canterbury for the loan of a high volume sampler.

Appendix 1: Ambient air quality monitoring results 2009

Table A1.1: Waione Street

Lab reference	Date On: 00:00	Date Off: 23:59	Flow Hrs	TSP (µg/m^3)	Lead (µg/m^3)	Arsenic (µg/m^3)
09/5239-02	05/03/2009	05/03/2009	24.12	29.53	0.018	0.0018
09/5240-02	07/03/2009	07/03/2009	23.98	35.33	0.073	0.0013
09/5473-02	09/03/2009	09/03/2009	23.99	23.50	0.013	0.0009
09/5662-02	11/03/2009	11/03/2009	23.99	53.78	0.040	0.0011
09/5752-02	13/03/2009	13/03/2009	23.99	45.05	0.021	0.0008
09/5952-02	15/03/2009	15/03/2009	23.99	18.93	0.006	0.0020
09/6096-02	17/03/2009	17/03/2009	23.98	18.95	0.019	0.0014
09/6210-02	19/03/2009	19/03/2009	23.99	35.06	0.113	0.0017
09/6361-02	21/03/2009	21/03/2009	23.98	26.75	0.016	0.0014
09/6426-02	23/03/2009	23/03/2009	23.98	32.87	0.006	0.0010
09/6660-02	25/03/2009	25/03/2009	23.98	17.09	0.041	0.0019
09/6721-02	27/03/2009	27/03/2009	23.98	36.04	0.153	0.0019
09/6943-02	29/03/2009	29/03/2009	22.99	24.02	0.105	0.0018
09/7211-01	31/03/2009	31/03/2009	23.98	25.63	0.008	0.0010
09/7274-02	02/04/2009	02/04/2009	23.98	25.60	0.023	0.0042
09/7346-02	04/04/2009	04/04/2009	23.98	2.80	0.047	0.0023
09/7605-02	06/04/2009	06/04/2009	23.98	23.93	0.036	0.0009
09/7778-02	08/04/2009	08/04/2009	23.98	26.18	0.030	0.0014
09/7779-02	10/04/2009	10/04/2009	23.99	18.70	0.011	0.0111
09/7880-02	12/04/2009	12/04/2009	23.98	18.60	0.009	0.0052
09/8238-02	16/04/2009	16/04/2009	23.99	3.76	0.056	0.0014
09/8239-02	18/04/2009	18/04/2009	23.99	12.31	0.011	0.0040
09/8540-02	20/04/2009	20/04/2009	23.98	25.39	0.008	0.0022
09/8721-02	22/04/2009	22/04/2009	23.99	27.06	0.021	0.0091
09/8735-02	24/04/2009	24/04/2009	23.99	33.22	0.020	0.0130
09/9070-02	28/04/2009	28/04/2009	23.99	32.19	0.065	0.0018
09/9139-02	30/04/2009	30/04/2009	24.01	13.89	0.005	0.0012
09/9307-02	02/05/2009	02/05/2009	23.99	24.79	0.014	0.0080
09/9563-02	04/05/2009	04/05/2009	23.99	45.95	0.028	0.0236
09/9652-02	06/05/2009	06/05/2009	23.99	35.40	0.009	0.0003
09/9893-02	08/05/2009	08/05/2009	23.98	26.41	0.034	0.0008
09/10118-02	10/05/2009	10/05/2009	23.98	17.83	0.012	0.0011
09/10147-02	14/05/2009	14/05/2009	23.98	32.59	0.061	0.0013
09/10352-02	16/05/2009	16/05/2009	23.98	44.50	0.085	0.0013
09/10543-02	18/05/2009	18/05/2009	24.01	29.71	0.060	0.0026
09/10620-02	20/05/2009	20/05/2009	23.98	78.78	0.019	0.0002
09/10812-02	22/05/2009	22/05/2009	23.98	67.39	0.014	0.0061

Lab reference	Date On: 00:00	Date Off: 23:59	Flow Hrs	TSP (µg/m³)	Lead (µg/m³)	Arsenic (µg/m³)
09/10845-02	24/05/2009	24/05/2009	24.01	50.12	0.001	0.0002
09/11004-02	26/05/2009	26/05/2009	23.99	9.88	0.006	0.0002
09/11149-02	28/05/2009	28/05/2009	23.98	26.51	0.087	0.0071
09/11154-02	30/05/2009	30/05/2009	23.98	33.95	0.032	0.0255
09/11371-02	01/06/2009	01/06/2009	23.98	34.94	0.003	0.0002
09/11619-02	03/06/2009	03/06/2009	23.98	39.98	0.256	0.0167
09/11730-02	05/06/2009	05/06/2009	23.98	26.29	0.046	0.0074
09/11840-02	07/06/2009	07/06/2009	24.02	22.71	0.012	0.0080
09/12174-02	09/06/2009	09/06/2009	23.99	30.38	0.026	0.0161
09/12242-02	11/06/2009	11/06/2009	23.99	19.47	0.025	0.0038
09/12334-02	13/06/2009	13/06/2009	23.98	15.61	0.007	0.0062
09/12452-02	15/06/2009	15/06/2009	23.98	23.17	0.044	0.0018
09/12631-02	17/06/2009	17/06/2009	23.99	39.10	0.023	0.0045
09/12723-02	19/06/2009	19/06/2009	23.99	39.26	0.014	0.0029
09/12777-02	21/06/2009	21/06/2009	23.98	25.99	0.002	0.0002
09/13076-02	23/06/2009	23/06/2009	24.00	30.28	0.012	0.0082
09/13078-02	25/06/2009	25/06/2009	24.01	28.25	0.150	0.0044
09/13243-02	27/06/2009	27/06/2009	24.00	21.47	0.054	0.0154
09/13359-02	29/06/2009	29/06/2009	23.98	7.22	0.004	0.0002
09/13495-02	01/07/2009	01/07/2009	24.02	43.05	0.039	0.0076
09/13572-02	03/07/2009	03/07/2009	23.98	20.73	0.058	0.0020
09/13701-02	05/07/2009	05/07/2009	24.01	8.84	0.001	0.0003

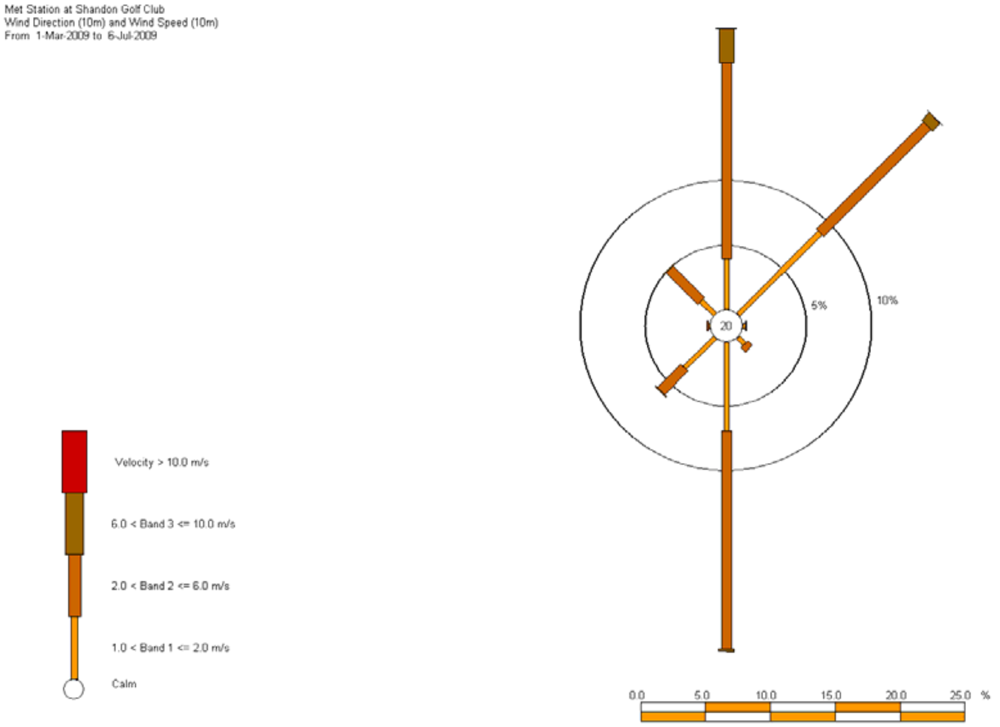
Table A1.2: Kirkcaldy Street

Lab reference	Date On: 00:00	Date Off: 23:59	Flow Hrs	TSP (µg/m³)	Lead (µg/m³)	Arsenic (µg/m³)
09/4741-01	01/03/2009	01/03/2009	24.00	14.02	0.005	0.0008
09/5129-01	03/03/2009	03/03/2009	23.99	21.79	0.012	0.0007
09/5239-01	05/03/2009	05/03/2009	23.99	26.42	0.028	0.0016
09/5240-01	07/03/2009	07/03/2009	24.00	17.81	0.008	0.0010
09/5473-01	09/03/2009	09/03/2009	23.99	23.75	0.015	0.0008
09/5662-01	11/03/2009	11/03/2009	23.98	52.55	0.043	0.0009
09/5752-01	13/03/2009	13/03/2009	23.98	45.26	0.020	0.0006
09/5952-01	15/03/2009	15/03/2009	23.99	20.03	0.030	0.0019
09/6096-01	17/03/2009	17/03/2009	23.98	15.39	0.039	0.0014
09/6210-01	19/03/2009	19/03/2009	23.98	29.85	0.011	0.0011
09/6361-01	21/03/2009	21/03/2009	24.02	32.85	0.059	0.0016
09/6426-01	23/03/2009	23/03/2009	23.99	31.81	0.006	0.0009
09/6660-01	25/03/2009	25/03/2009	23.98	11.97	0.057	0.0017
09/6721-01	27/03/2009	27/03/2009	23.98	27.85	0.070	0.0013
09/6943-01	29/03/2009	29/03/2009	22.98	26.84	0.042	0.0011
09/7211-02	31/03/2009	31/03/2009	23.99	26.79	0.021	0.0010
09/7274-01	02/04/2009	02/04/2009	23.98	19.90	0.058	0.0042
09/7346-01	04/04/2009	04/04/2009	23.98	18.02	0.050	0.0022
09/7605-01	06/04/2009	06/04/2009	23.99	14.44	0.058	0.0011
09/7778-01	08/04/2009	08/04/2009	23.99	17.83	0.006	0.0013
09/7779-01	10/04/2009	10/04/2009	24.03	19.46	0.018	0.0130
09/7880-01	12/04/2009	12/04/2009	23.97	17.75	0.014	0.0050
09/8017-01	14/04/2009	14/04/2009	23.99	28.01	0.013	0.0041
09/8238-01	16/04/2009	16/04/2009	23.98	18.17	0.038	0.0013
09/8239-01	18/04/2009	18/04/2009	23.98	10.39	0.020	0.0036
09/8540-01	20/04/2009	20/04/2009	23.98	28.38	0.010	0.0022
09/8721-01	22/04/2009	22/04/2009	23.99	22.94	0.025	0.0083
09/8735-01	24/04/2009	24/04/2009	23.99	27.60	0.036	0.0113
09/8800-01	26/04/2009	26/04/2009	23.98	18.75	0.018	0.0021
09/9070-01	28/04/2009	28/04/2009	23.98	11.47	0.012	0.0015
09/9139-01	30/04/2009	30/04/2009	23.98	10.19	0.003	0.0010
09/9307-01	02/05/2009	02/05/2009	23.99	17.36	0.042	0.0076
09/9563-01	04/05/2009	04/05/2009	23.98	26.26	0.020	0.0167
09/9652-01	06/05/2009	06/05/2009	23.98	28.66	0.003	0.0003
09/9893-01	08/05/2009	08/05/2009	23.98	18.91	0.002	0.0008
09/10118-01	10/05/2009	10/05/2009	23.98	13.12	0.004	0.0010
09/10147-01	14/05/2009	14/05/2009	24.00	19.63	0.018	0.0009
09/10352-01	16/05/2009	16/05/2009	23.98	27.51	0.005	0.0006
09/10543-01	18/05/2009	18/05/2009	23.98	17.95	0.005	0.0023

Lab reference	Date On: 00:00	Date Off: 23:59	Flow Hrs	TSP (µg/m^3)	Lead (µg/m^3)	Arsenic (µg/m^3)
09/10620-01	20/05/2009	20/05/2009	23.99	63.67	0.006	0.0002
09/10812-01	22/05/2009	22/05/2009	23.98	51.98	0.006	0.0058
09/10845-01	24/05/2009	24/05/2009	24.00	31.14	0.000	0.0002
09/11004-01	26/05/2009	26/05/2009	23.98	9.94	0.007	0.0002
09/11149-01	28/05/2009	28/05/2009	24.70	11.80	0.021	0.0061
09/11154-01	30/05/2009	30/05/2009	23.99	24.65	0.041	0.0231
09/11371-01	01/06/2009	01/06/2009	23.98	28.30	0.002	0.0002
09/11619-01	03/06/2009	03/06/2009	23.99	32.31	0.054	0.0155
09/11730-01	05/06/2009	05/06/2009	23.98	11.82	0.020	0.0066
09/11840-01	07/06/2009	07/06/2009	24.00	23.34	0.019	0.0074
09/12174-01	09/06/2009	09/06/2009	23.99	20.74	0.026	0.0155
09/12242-01	11/06/2009	11/06/2009	23.98	9.92	0.008	0.0034
09/12334-01	13/06/2009	13/06/2009	23.99	10.96	0.005	0.0061
09/12452-01	15/06/2009	15/06/2009	23.98	12.90	0.024	0.0017
09/12723-01	19/06/2009	19/06/2009	23.98	28.81	0.034	0.0025
09/12777-01	21/06/2009	21/06/2009	23.98	22.53	0.001	0.0002
09/13076-01	23/06/2009	23/06/2009	24.00	22.63	0.014	0.0081
09/13078-01	25/06/2009	25/06/2009	24.00	16.78	0.022	0.0041
09/13243-01	27/06/2009	27/06/2009	24.00	16.74	0.027	0.0137
09/13359-01	29/06/2009	29/06/2009	23.98	7.65	0.002	0.0002
09/13495-01	01/07/2009	01/07/2009	23.67	34.46	0.032	0.0074
09/13572-01	03/07/2009	03/07/2009	23.99	11.05	0.019	0.0016
09/13701-01	05/07/2009	05/07/2009	24.06	8.13	0.003	0.0003

Appendix 2: Wind rose

The wind rose is derived from data collected at Shandon Golf Course (NZMS 260:R27:E2669020; N5996170), approximately 750 m north-east of the monitoring sites. The wind rose shows the percentage frequency of wind speeds (metres per second) recorded in five wind speed bands by eight wind direction ranges. The number in the centre of the rose is the percentage frequency calms (defined as wind speeds less than 1 m/s). The bar points towards the direction the wind is blowing from.

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~~~ Hilltop Hydro ~~~ Version 5.83                                         3-Sep-2009
~~~ PLWind ~~~

Source is \\zeus\dbase\Raw\telemetry.hts
Wind Direction (10m) and Wind Speed (10m) at Met Station at Shandon Golf Club
From  1-Mar-2009 00:00:00 to  6-Jul-2009 00:00:00

Number of data points read               :   18288
Number of Velocities outside limits      :       0
Number of Directions <0.0 or >360.0 deg. :       0
Number of Data points used               :   18288
Limits of valid velocities is 0.0 to 50.0 m/s

                        Percentange of time in each band
  Direction        Band 1      Band 2      Band 3      Band 4         Total
337.5 -  22.4        4.0        15.1         2.6         0.1          21.7
 22.5 -  67.4        9.0        11.7         0.8         0.0          21.5
 67.5 - 112.4        0.2         0.0         0.0         0.0           0.3
112.5 - 157.4        0.7         0.5         0.0         0.0           1.2
157.5 - 202.4        6.9        16.7         0.3         0.0          23.9
202.5 - 247.4        3.3         2.5         0.1         0.0           5.9
247.5 - 292.4        0.1         0.1         0.0         0.0           0.2
292.5 - 337.4        1.5         3.4         0.1         0.0           5.0
        Total       25.7        50.1         3.9         0.1          79.7
                                                   Percentage Calm    20.3
Velocity band ranges (m/s)
        Calm  <=  1.0     1.0 < Band 1 <=  2.0
 2.0 < Band 2 <=  6.0     6.0 < Band 3 <= 10.0
       Band 4 >  10.0
```

Appendix 3: Descriptive statistics

Table A3.1: Summary statistics for TSP concentrations (1 March to 5 July 2009)

TSP (µg/m^3) 24-hour average	Waione Street	Kirkcaldy Street
Maximum	78.78	63.67
99.9th percentile	78.12	62.99
99th percentile	72.17	56.89
95th percentile	50.49	44.72
75th percentile	35.00	27.79
25th percentile	20.10	14.68
Mean	28.59	22.42
95% confidence interval of mean	26.00 - 32.18	19.42 - 25.19
Standard deviation	13.78	10.93
Variance	189.82	119.5
Median	26.41	19.97
MAD (median absolute deviation)	11.09	10.33
Sample size	59	62

Table A3.2: Summary statistics for Lead concentrations (1 March to 5 July 2009)

Lead (µg/m^3) in TSP 24-hour average	Waione Street	Kirkcaldy Street
Maximum	0.256	0.070
99.9th percentile	0.250	0.069
99th percentile	0.196	0.063
95th percentile	0.117	0.058
75th percentile	0.046	0.031
25th percentile	0.011	0.006
Mean	0.037	0.022
95% confidence interval of mean	0.026 - 0.049	0.017 - 0.026
Median	0.021	0.018
Standard deviation	0.0448	0.0177
Variance	0.002	$3e^{-04}$

Lead (µg/m³) in TSP 24-hour average	Waione Street	Kirkcaldy Street
MAD (median absolute deviation)	0.0222	0.0185
Sample size	59	62

Table A3.3: Summary statistics for arsenic concentrations (1 March to 5 July 2009)

Arsenic (µg/m³) in TSP 24-hour average	Waione Street	Kirkcaldy Street
Maximum	0.0255	0.0231
99.9th percentile	0.0254	0.0217
99th percentile	0.0244	0.0192
95th percentile	0.0162	0.0154
75th percentile	0.0062	0.0056
25th percentile	0.0011	0.0009
Mean	0.0044	0.0039
95% confidence interval of mean	0.0030 - 0.0059	0.0026 - 0.0041
Standard deviation	0.0056	0.0049
Variance	$3e^{-05}$	$2e^{-05}$
Median	0.0019	0.0016
MAD (median absolute deviation)	0.0024	0.0015
Sample size	59	62

Table A3.4: Summary statistics for lead in air in 1999

Lead µg/m³ in TSP (24-hour average)	Waione Street	Kirkcaldy Street
Median	0.21	0.06
Mean	0.31	0.10
Maximum	1.25	0.60
Minimum	0.010	0.010
Sample size	43	42

Water, air, earth and energy – elements in Greater Wellington's logo that combine to create and sustain life. Greater Wellington promotes **Quality for Life** by ensuring our environment is protected while meeting the economic, cultural and social needs of the community

For more information, contact Greater Wellington:

Wellington office
PO Box 11646
Manners Street
Wellington 6142
T 04 384 5708
F 04 385 6960

Masterton office
PO Box 41
Masterton 5840
T 06 378 2484
F 06 378 2146

GW/EMI-G-09/277
November 2009

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