Rio Tinto

KMP SO_2 EEM Program – Technical Memo P05

Atmospheric Sulphur Dioxide

Passive Diffusive Sampler Network: 2017 Results

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1 Overview

During 2017, the sulphur dioxide (SO_2) passive diffusive sampler network in the Kitimat Valley began monitoring on 09 June and finished on 26 October, following (approximately) four one-month exposures. The Wedeene Road was closed during the scheduled September sampler change-over, owing to heavy rains, resulting in a 78 day exposure. Further closures on Bish Road delayed collection for sites V11, V12 and V13 until 14 November, resulting in a 97 day exposure. Nonetheless, passive samplers appeared to have performed well, showing similar results to 2016.

The Kitimat Urban SO_2 passive diffusive sampler network was initially to be replaced by a multi-season (year long) study. However, this was delayed until 2018. As such, the urban network was re-established on 10 July and finished on 11 October, following three one-month exposures.

This memo presents the results of the SO_2 passive diffusive samplers during 2017.

2 Study Design

The 2017 monitoring employed the same procedures as 2016, with only minor modifications to the total number of monitoring sites (see Appendix A Table A1); the Valley network added four new sites and decommissioned one (total of 20 sites), and the Urban network was reduced by two sites (total of 13 sites). Sites V04B and V07B were added to the Valley network to assess low and high concentrations observed during 2016, V13 was added to Bish Road to extend the network further south, and V14 (Kitimat Service Centre) was moved from the Urban network (originally U12 in 2016). Sites V00 (HWY37) and U15 (Kitamaat) were removed as they provided limited information (See Appendix A Figure A1 and A2). During 2017, there were 33 monitoring sites with 99 valid sample exposures across both networks, with duplicate samplers deployed >30% of the time.

3 Results

The observed data showed elevated atmospheric SO_2 along the plume path (a transect of approximately 45–50 km; Figure 1 and Appendix Table A2 and Figure A1); notably during June–August plume concentrations were high north of Rio Tinto (concentrations > 10 $\mu g\ m^{-3}$ (> 3ppb) were observed at the Rife Range monitoring site), and during August–October higher concentrations were observed south of Rio Tinto (concentrations > 18 $\mu g\ m^{-3}$ (> 7 ppb) were observed at Bish Road).

In contrast, all monthly exposures under the urban network were consistently < 1.3 $\mu g\ m^{-3}$ (Figure 1). Nonetheless, average air concentrations during 2017 across the Urban network increased by about 30% compared with 2016 observations. Similarly, the average air concentrations during 2017 across the Valley network increased by > 35% compared with 2016 observations (see Technical Memo P04: Passive Diffusive Sampler Network: 2016 Results)

The concentration of SO_2 measured by passive samplers was also compared to the active observations at three ambient stations to evaluate sampler performance (Haul Road, Riverlodge and Whitesail; summarised to coincide with the monthly passive sampler exposure periods). In general, there was good correspondence between passive and active (R^2 = 0.99); however, the one-to-one regression slope suggests that passive samplers represented < 80% of the SO_2 concentrations reported by the active samplers (see Figure 2). This difference is similar to the variation between duplicate sampler exposures, i.e., on average there was ~11% variation between duplicate samplers (see Appendix Table A3). Moreover, the comparison against the active stations suggests a larger deviation at stations with low atmospheric SO_2 concentrations (see Whitesail in Figure).

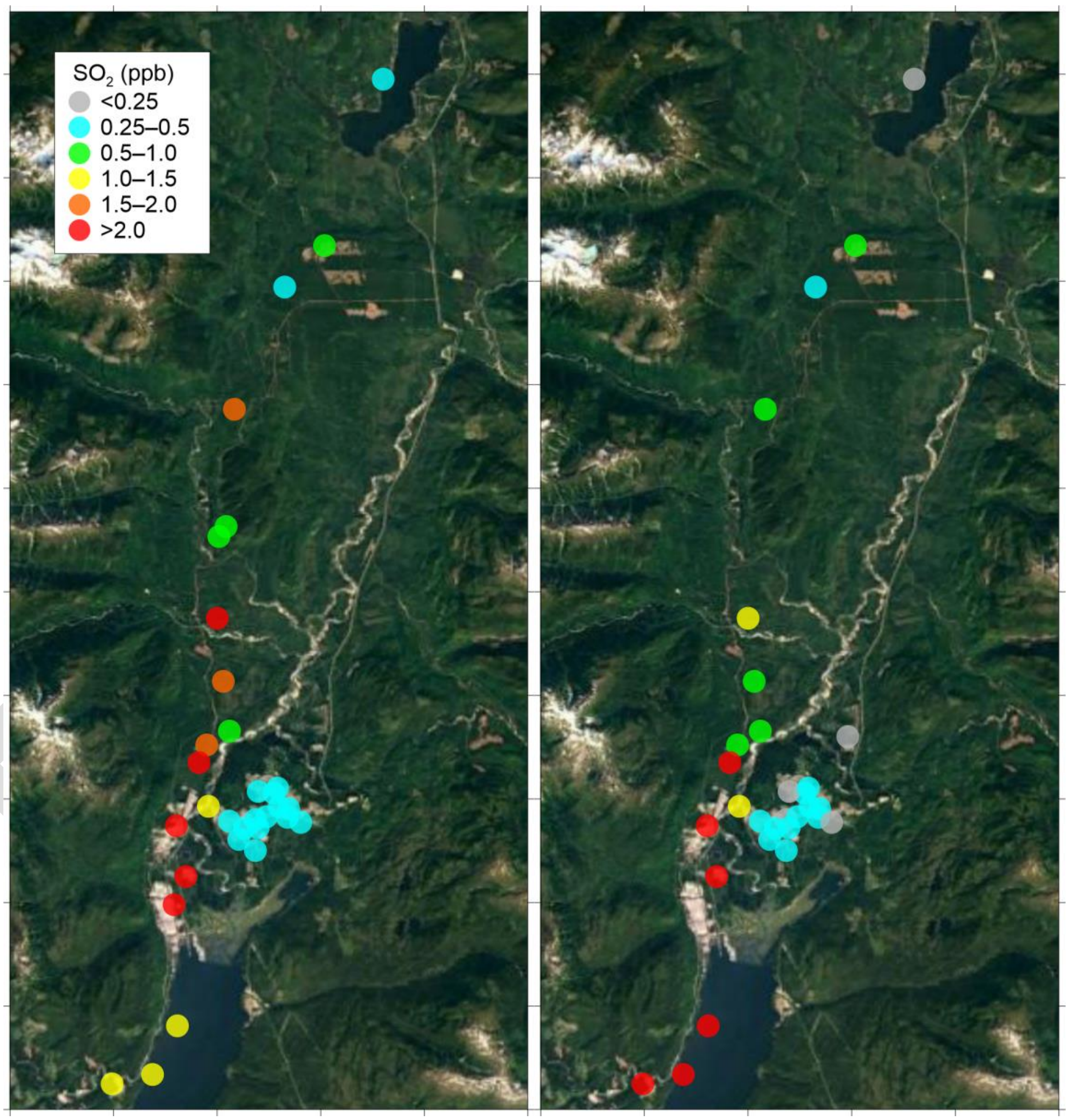

Figure 1. Average atmospheric sulphur dioxide (SO_2) concentration during June–August (left) and August–October (right) 2017 in the Kitimat Valley and Urban passive diffusive monitoring networks (ppb [= µg m^{-3} ÷ 2.62]). Note: monthly exposures under the Kitimat urban network started 10 July during 2017.

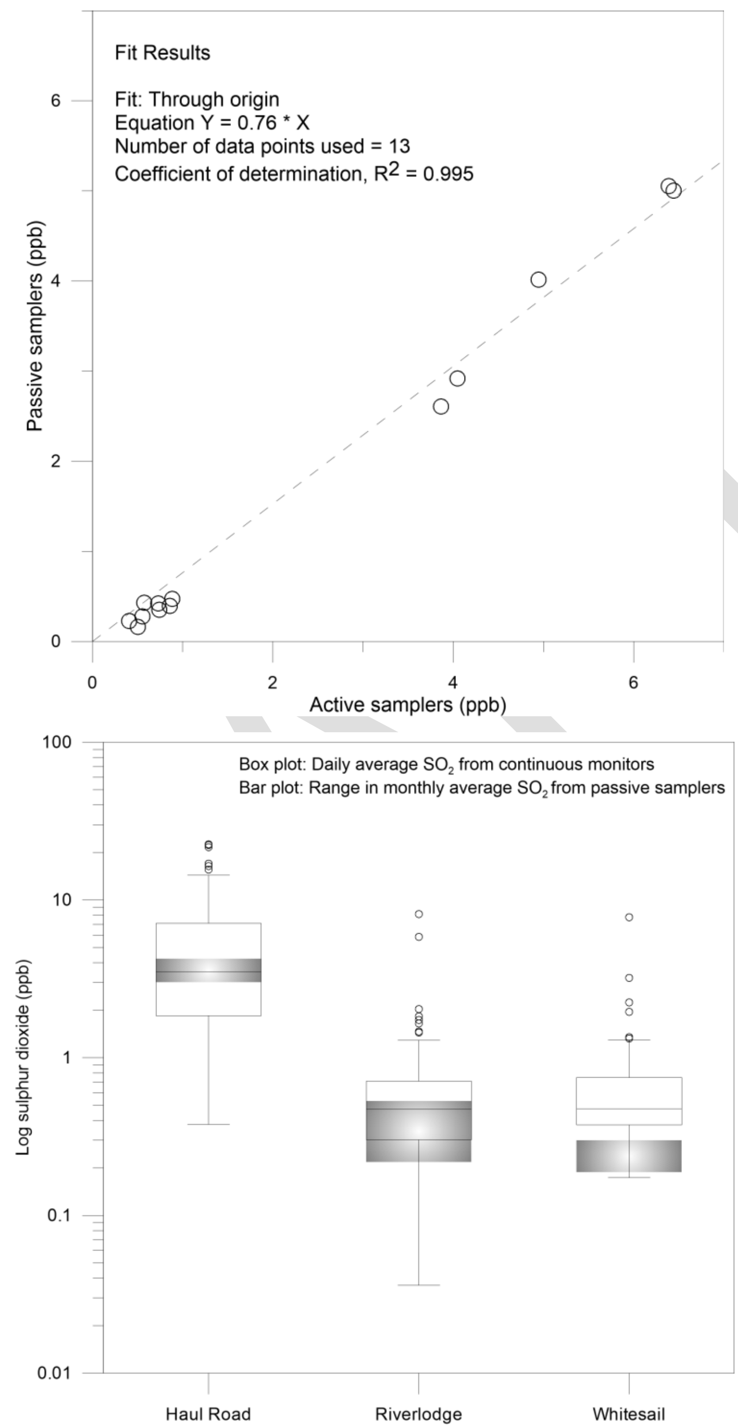

Figure 2. Comparison of IVL passive diffusive samplers for sulphur dioxide (SO_2) against continuous measurements (μg m^{-3}) at Haul Road, Riverlodge and Whitesail during 09 June–27 October 2017. Passive samplers were exposed at each station for one month (see Appendix A for exposure dates). The scatter plot (upper) includes a linear regression of active against passive (R^2 = 0.99). However, passive SO_2 observations are lower than active at Riverlodge and Whitesail (as show in the scatter [upper] and bar [lower] plots).

4 Conclusion

The 2017 results demonstrate a similar spatial pattern in SO_2 compared with 2016; however, atmospheric concentrations have increased by > 30% across all sites in 2017 during the same monitoring period.

In summary, the results from the 2017 network continue to support the use of passive samplers to provide empirical observations of atmospheric SO_2 concentrations to (a) assess spatial and temporal changes, (b) evaluate modelled concentration fields, and (c) estimate dry deposition of SO_2. It is recommended that deployments are continued during 2018.

5 Literature Cited

Technical Memo P04: Passive Diffusive Sampler Network: 2016 Results, March 2017. In, Sulphur Dioxide Environmental Effects Monitoring for the Kitimat Modernization Project, 2015 Annual Reports. ESSA Technologies Ltd, Vancouver, Canada.

Appendix A.

Table A1. Location of passive diffusive sampler monitoring sites established and deployed during June–October (V and A sites) and July–October (U sites) 2017. Note: V denotes Valley, A denotes Ambient stations, and U denotes Urban sites. See Figures A1 and A2 for mapped site locations.

ID	Site Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (m)
V01	Onion Lake Ski Trail North	54.3044	-128.6166	215
V02	Wedeene Road West km 9	54.2859	-128.6447	197
V03	Mound TKTP92	54.2323	-128.6789	127
V04	ENSO north	54.1813	-128.6818	94
V04B	ENSO south	54.1769	-128.6869	109
V05	LNG Muster Station	54.1414	-128.6856	114
V06	Sand Pit	54.1144	-128.6796	67
V07	Wedeene at Powerline	54.0929	-128.6734	26
V07B	Gravel Pit road at Powerline	54.0865	-128.6899	73
V08	Claque Mountain Trail at Powerline	54.0787	-128.6953	68
V09	Sand Hill at Powerline	54.0511	-128.7101	156
V10	Rifle Range	54.0169	-128.7096	35
V11	Bish Road 4.1 km	53.9647	-128.7039	40
V12	Bish Road Pullout 4	53.9432	-128.7206	114
V13	Bish Road at Chevron LNG	53.9383	-128.7501	76
V14	Industrial area Kitimat Hotel	54.0600	-128.6870	2
A01	Haul Road station	54.0293	-128.7019	10
A02	Riverlodge station	54.0540	-128.6710	17
A03	Whitesail station	54.0669	-128.6391	92
A04	Lakelse Lake NADP station	54.3772	-128.5773	112
U01	Low Channel	54.0463	-128.6636	11
U02	Kitimat City Centre MAML	54.0551	-128.6520	30
U03	Nechako Elementary	54.0566	-128.6281	94
U04	Mount Elizabeth School	54.0603	-128.6278	94
U05	Cable Car residential area	54.0919	-128.6085	50
U06	Kitimat General Hospital	54.0515	-128.6495	19
U07	Blueberry Street	54.0418	-128.6512	12
U08	Anderson Street	54.0673	-128.6506	92
U09	Fulmar Street	54.0610	-128.6346	88
U10	Kitimat Valley Institute	54.0690	-128.6362	98
U11	Kitimat City High	54.0564	-128.6439	86
U13	St. Anthony's Elementary	54.0547	-128.6184	92
U14	Kildala Elementary	54.0510	-128.6596	16

Table A2. Results of the passive diffusive sampler monitoring network for June–October 2017. Atmospheric sulphur dioxide concentrations (μg m^{-3} [= ppb × 2.62]) are presented for each exposure (E01–E04), the average (AVE) and relative standard deviation (COV) between the four exposures is presented; in addition, the averages for the first two (JJA: June–July–August) and second two (ASO: August–September–October) exposures are also shown. See Table A1 for site locations and Figure A1 for map of average concentrations over the four exposures.

ID	E01	E02	E03	E04	AVE	COV	JJA	ASO
			(μg m^{-3})			(%)	(μg m^{-3})	
V01	2.274	1.803	1.840		1.97	13.3	2.039	1.840
V02	0.312	1.834	1.211		1.12	68.4	1.073	1.211
V03	4.819	3.662	2.269		3.58	35.6	4.241	2.269
V04	2.442	1.652			2.05	27.3	2.047	
V04B	2.440	1.852			2.15	19.4	2.146	
V05	6.524	5.909	3.804		5.41	26.4	6.216	3.804
V06	5.114	4.678	1.891		3.89	44.9	4.896	1.891
V07	2.349	2.322	1.572		2.08	21.2	2.335	1.572
V07B	4.336	3.843	2.275		3.48	30.9	4.089	2.275
V08		6.927	5.440		6.18	17.0	6.927	5.440
V09	10.211	8.155	5.267		7.88	31.5	9.183	5.267
V10	11.748	9.052			10.40	18.3	10.400	
V11	1.774	3.512	18.453		7.91	115.9	2.643	18.453
V12	1.778	4.268	10.029		5.36	79.0	3.023	10.029
V13	2.275	3.946	10.282		5.50	76.8	3.111	10.282
V14	4.026	2.845	2.956		3.28	19.9	3.435	2.956
A01	13.744	7.032	13.558	8.054	10.73	28.8	10.388	10.806
A02	1.155	1.168	0.761	1.311	1.01	28.6	1.162	1.036
A03		0.955	0.456	1.090	0.83	40.1	0.955	0.773
A04	0.934	0.913	0.807	0.374	0.76	34.6	0.924	0.590
U01		1.227	0.603	0.903	0.91	34.3	1.227	0.753
U02		1.036	0.481	0.752	0.76	36.7	1.036	0.616
U03		0.956	0.547	0.802	0.77	26.9	0.956	0.674
U04		0.918	0.531	1.115	0.85	34.8	0.918	0.823
U05			0.195	0.458	0.33	56.9		0.327
U06		1.051	0.616	0.961	0.88	26.2	1.051	0.789
U07		1.075	0.565	0.785	0.81	31.7	1.075	0.675
U08		1.173	0.467	0.637	0.76	48.5	1.173	0.552
U09		1.079	0.583	0.951	0.87	29.6	1.079	0.767
U10		0.877	0.477	0.976	0.78	34.0	0.877	0.726
U11		1.156	0.528	1.113	0.93	37.6	1.156	0.821
U13		0.856	0.481	0.813	0.72	28.7	0.856	0.647
U14		1.198	0.645	0.823	0.89	31.8	1.198	0.734

E01 09 June to 10 July 2017 | Valley and Ambient only
E02 10 July to 09 August 2017
E03 U: 09 August to 13 September 2017 | V: 09 August to 26 October 2017[1]
E04 13 September to 11 October 2017 | Urban and Ambient only
E05 11 October to 26 October 2017 | A01 and A02 only (data shown in Table A3)

[1] E03 09 August to 14 November 2017 for V11, V12 and V13

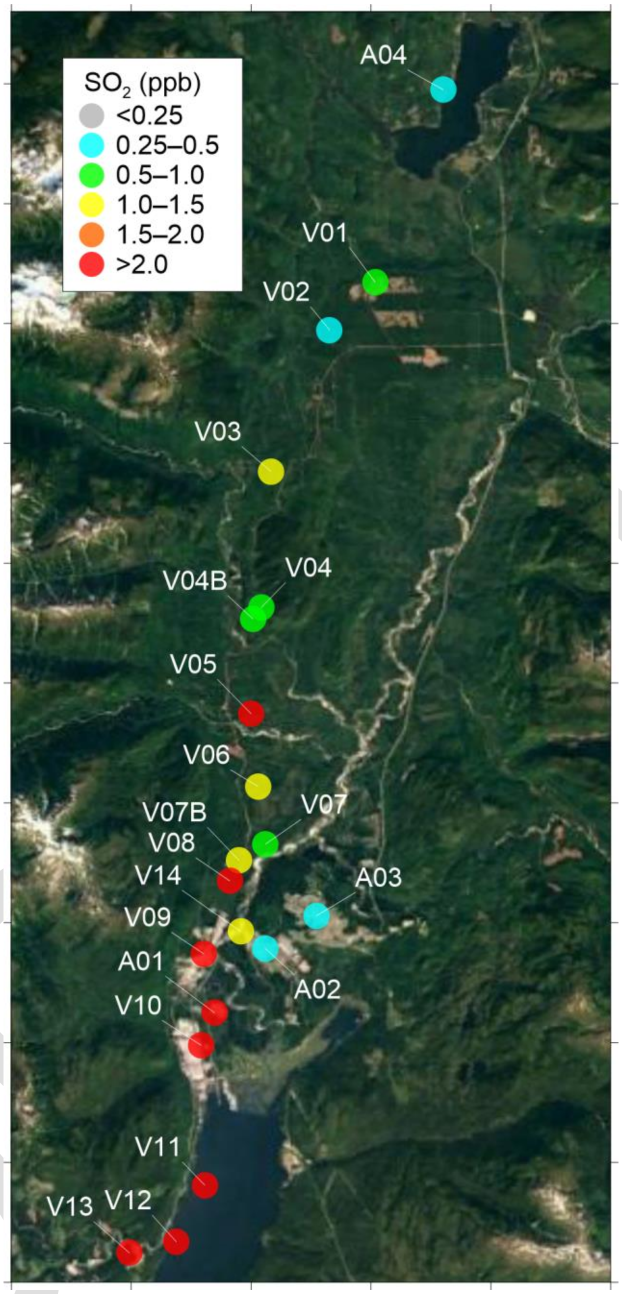

Figure A1. Average atmospheric sulphur dioxide (SO_2) concentration (ppb = [μg m^{-3} ÷ 2.62]) during June–October 2017 (average of three or four monthly exposures) in the Kitimat valley (V) and ambient (A) passive diffusive monitoring networks. Site IDs are shown for the Kitimat valley network, see Figure A2 for remaining sites.

Figure A2. Site locations and IDs for the Kitimat urban (U) and ambient (A) passive diffusive sampler network; see Figure A1 and Table A1 for further details on site locations.

Table A3. Analysis of replicated passive diffusive sampler deployments during exposures 1 to 5. The average and the percent difference between the two replicates are presented. Replicate exposures with a difference greater than 25% are highlighted. See Table A1 for a description of the Site ID (SID).

Exposure	SID	Sampler A	Sampler B	Average	Difference
			(µg m^{-3})		%
1	A02	1.18	1.13	1.16	3.7
1	A04	1.06	0.81	0.93	26.1
1	V03	5.30	4.34	4.82	20.0
1	V04B	2.39	2.50	2.44	4.5
1	V07B	3.95	4.72	4.34	17.9
1	V13	2.06	2.49	2.28	19.3
2	A03	0.95	0.96	0.95	1.9
2	A04	0.92	0.91	0.91	1.8
2	U03	0.96	0.95	0.96	1.0
2	U11	1.13	1.18	1.16	3.6
2	U14	1.26	1.14	1.20	9.7
2	V04	1.75	1.56	1.65	11.6
2	V07	2.12	2.52	2.32	17.3
2	V09	7.01	9.30	8.16	28.1
2	V12	4.26	4.27	4.27	0.3
3	A01	12.19	14.93	13.56	20.2
3	A02	0.76	0.76	0.76	0.6
3	A03	0.47	0.44	0.46	7.5
3	A04	0.81	0.80	0.81	1.2
3	U01	0.58	0.62	0.60	7.4
3	U04	0.52	0.54	0.53	2.9
3	U05	0.20	0.19	0.20	4.5
3	U09	0.63	0.54	0.58	16.1
3	V02	1.12	1.30	1.21	14.8
3	V05	4.03	3.57	3.80	12.2
3	V11	19.33	17.58	18.45	9.5
3	V14	2.86	3.05	2.96	6.2
4	A01	7.79	8.32	8.05	6.5
4	A02	1.27	1.35	1.31	6.4
4	A03	1.00	1.18	1.09	15.9
4	A04	0.32	0.42	0.37	26.2
4	U02	0.72	0.79	0.75	8.9
5	A01	12.32	10.20	11.26	18.9
5	A02	0.52	0.77	0.64	39.4

E01 09 June to 10 July 2017
E02 10 July to 09 August 2017
E03 U: 09 August to 13 September 2017 | V: 09 August to 26 October 2017
E04 13 September to 11 October 2017
E05 11 October to 26 October 2017