



**Analysis of the SO<sub>2</sub> levels  
measured at the  
Erie St., Victoria, BC  
monitoring site  
during the  
2012 cruise ship season**

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**James Bay Neighbourhood Association**

[www.jbna.org](http://www.jbna.org)

## Analysis of the SO<sub>2</sub> levels measured at the Erie St., Victoria, BC monitoring site during the 2012 Cruise Ship season (up to October 1st)

### Key Points

- The single SO<sub>2</sub> monitoring site is at Daniels Electronics located at 43 Erie St. This site is in the SW wind sector (p4).
- The wind direction (ships in port,  $\geq 2\text{m/s}$ ) was mainly from the SW (25%), WSW (23%), SSW (15%) and W (11%). The biggest change from 2011 was the reduction in West winds (18% in 2011, 11% in 2012) (p4).
- The recorded SO<sub>2</sub> levels for both the averages and the maxima are many times higher when ships are in port (p6, 7).
- The recorded SO<sub>2</sub> levels drop off sharply when the wind is not from the SW (p6) and when the wind speed is less than 15 knots. Additional monitoring sites are required to determine the locations in James Bay where low speed winds result in high SO<sub>2</sub> levels (p9).
- The monitor captures the SO<sub>2</sub> levels at the single Erie St. location; it captures values indicative of the actual ship emissions only 3% of the time that ships are in port (p9, 10, 18).
- On August 1<sup>st</sup>, 2012 new regulations for the North American Emission Control Area (ECA) came into effect. Ships operating within this area must now burn fuel with a sulphur content not exceeding 1%.
- Both the average and maximum SO<sub>2</sub> levels measured at Erie St. were lower post-ECA than pre-ECA when the winds were from the SW (p6, 7).
- The % of times the SO<sub>2</sub> levels were under the 35 ppb threshold (as defined on p10), with winds from the SW, was significantly less post-August 1<sup>st</sup> (p18).
- The previous two points are, however, based on the small number of hours that the wind was from the SW and towards the Erie St. monitoring site (107 pre and 49 hours post-August 1<sup>st</sup> out of a total of 1232 hours the ships were in port) (p18). Additional monitoring sites would have been needed to provide a more definitive indication of an improvement.
- Although not as marked, there was also an improvement in the SO<sub>2</sub> levels measured post-August 1<sup>st</sup> in 2011 (11.8 pre vs. 9.8 ppb post for SW winds). i.e. several factors (number of ships, which ships, wind conditions), in addition to fuel type, will affect the average SO<sub>2</sub> levels
- The average SO<sub>2</sub> level, when the wind was from the WSW was higher post-August 1<sup>st</sup> than both pre-August 1<sup>st</sup> and in 2011 (p6,18).
- The emphasis should now be on identifying and naming those ships which are in port when the highest levels of SO<sub>2</sub> are recorded. This is far more likely to lead to reductions in the overall SO<sub>2</sub> levels than the not very exacting standard required to achieve the GVHA-sponsored "Ogden Point Eco Award".
- Additional monitoring sites are required to determine the full extent of the SO<sub>2</sub> levels experienced by the James Bay, Inner Harbour and the Songhees communities. The priority is a site in the WSW sector at a location closer to Ogden Point.

## **Methodology**

This analysis is based on available data for:

- 10-minute average wind speed and direction as measured at Ogden Point.
- Cruise ship scheduled arrival and departure times.
- Both the 10-minute and 1-hour average SO<sub>2</sub> levels measured at the Erie St. site.

The wind direction is very variable and can change significantly over a one hour period. As a result over a one hour period the SO<sub>2</sub> levels measured at the Erie St. site, in the SW sector, will often be “diluted” by diffused measurements due to winds from other directions and therefore be less indicative of the actual ship emissions. In order to reduce this effect some charts only include results when at least four of the 10-minute wind measurements were in the same direction as the 1-hour average. These charts will be labelled “4/6”.

The tables and graphs in this report will use two methods for presenting the data:

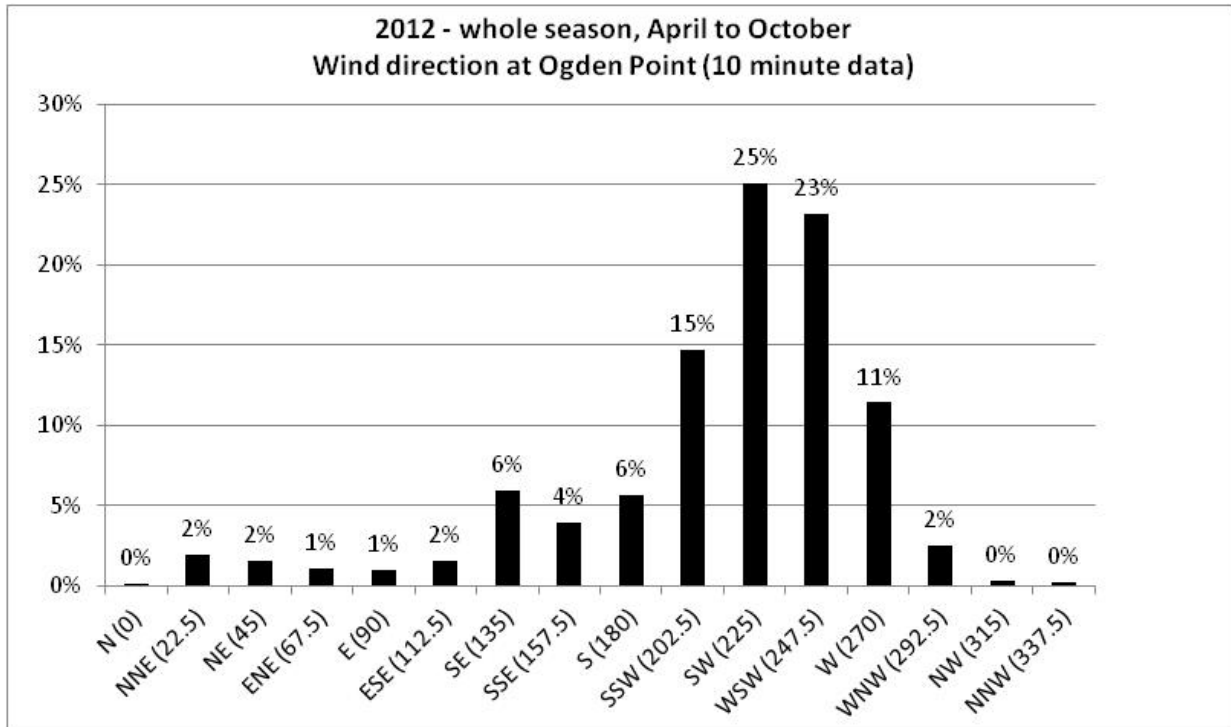
- **“1-hour average”** – Used when a comparison with the Vancouver Island Health Authority (VIHA) SO<sub>2</sub> 1-hr exposure guidelines is useful; e.g., when looking at actual SO<sub>2</sub> levels detected at the Erie site.
- **“10-minute average”** – used when a larger dataset will provide more accurate information and a comparison with health standards is not required; e.g., when calculating the % of the time the wind is from a SW direction.

Each table and chart is labelled with the method used.

## Wind Direction

The frequency of wind direction in each of 16 sectors (N, NNE, NE, ENE, E etc.), when cruise ships are in port, is shown in the chart below.

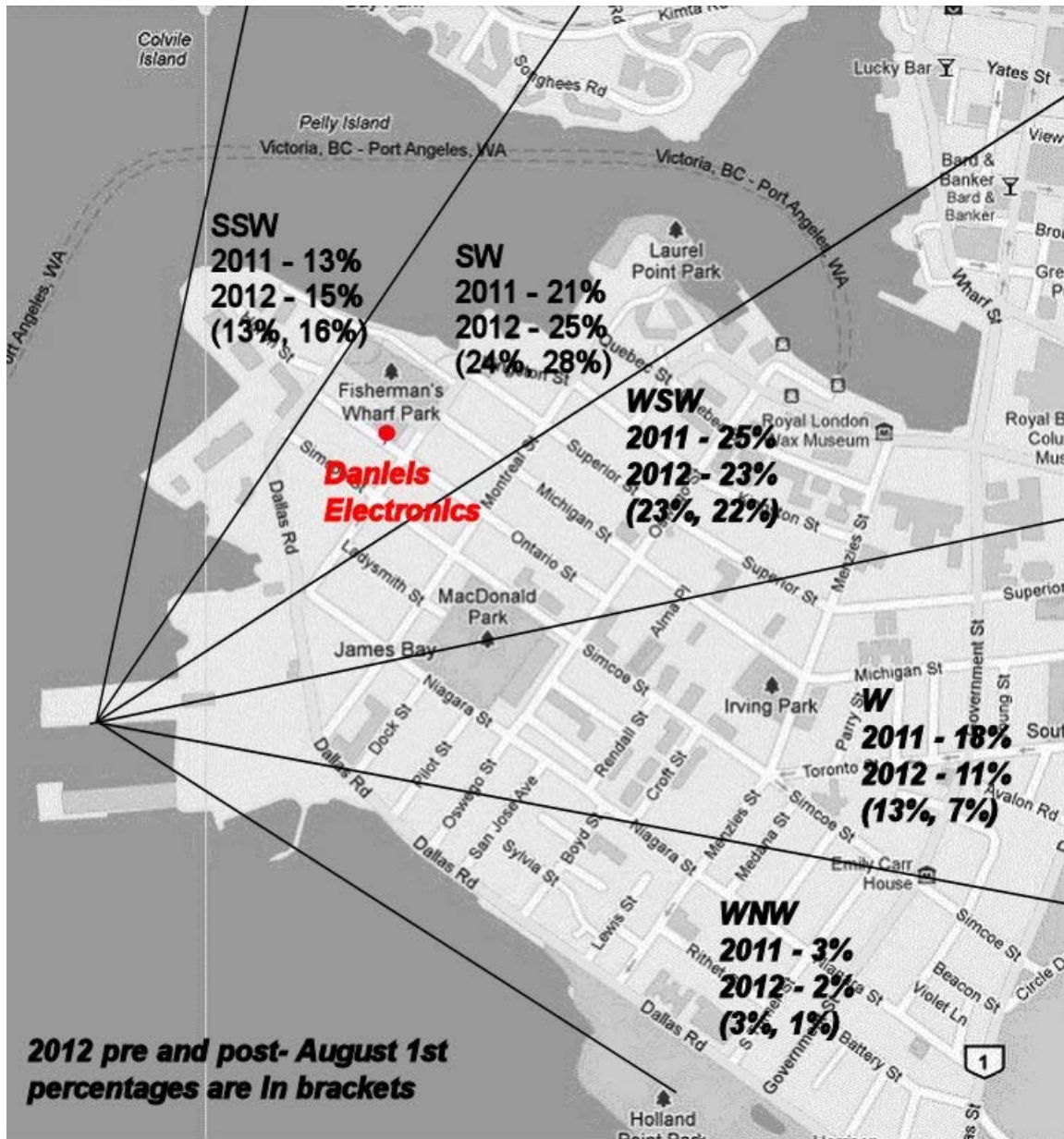
The Erie St. site is in the SW sector (213.75° to 236.25°). Its actual location relative to the cruise ship will vary between 215° and 230° depending on which pier is in use; i.e., it will most accurately capture ship emission data when the winds are from the SW. This occurred 25% of the times that the cruise ships have been docked.



The wind direction varies throughout the year with the SW winds being at their lowest in May and highest in August. The chart below is for the 5 (of 16) sectors which affect James Bay.

	May	Jun	Jul	Aug	Sep	Apr-Oct
SSW	5%	10%	23%	20%	15%	15%
SW	15%	21%	33%	31%	25%	25%
WSW	29%	18%	26%	23%	20%	23%
W	15%	24%	4%	6%	9%	11%
WNW	2%	7%	1%	0%	3%	2%
	65%	80%	86%	80%	73%	77%

**Wind directions in James Bay (as measured at the Ogden Point breakwater beacon)**



The wind direction (10-minute readings, ships in port) from Pier A at Ogden Point and the direction frequency have been superimposed on the above James Bay map. The location of the Erie St. SO<sub>2</sub> monitoring site is also indicated.

This chart compares the 2011 whole season, 2012 whole season and the pre-August 1<sup>st</sup> and post-August 1<sup>st</sup> and 2011 wind directions.

## **Average and Maximum SO<sub>2</sub> levels measured at Erie St.**

The three charts on each of the next two pages show the SO<sub>2</sub> levels measured at Erie St. during:

- 1) 2011 whole season – April to October
- 2) 2012 pre-August 1<sup>st</sup>
- 3) 2012 post-August 1<sup>st</sup>

Of note for the “average” readings are:

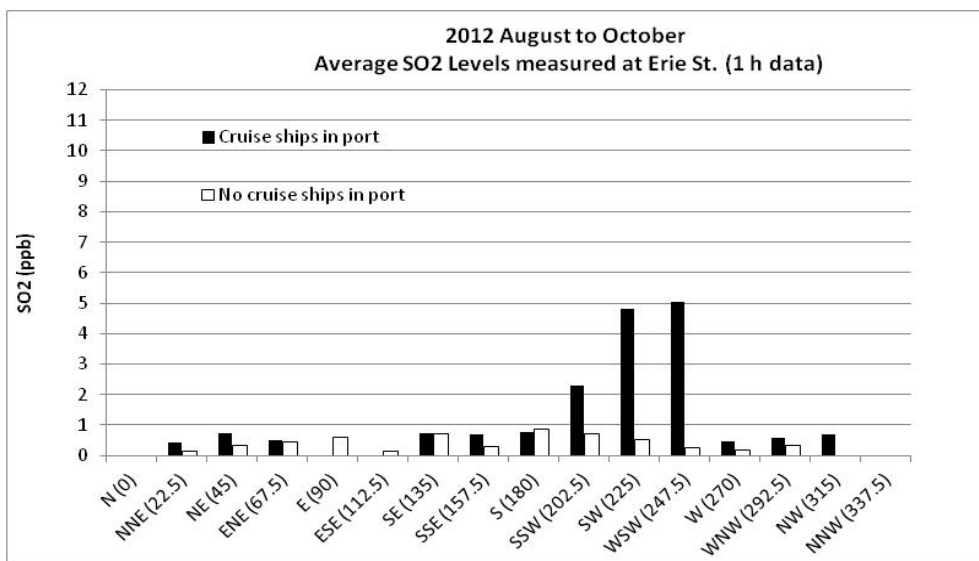
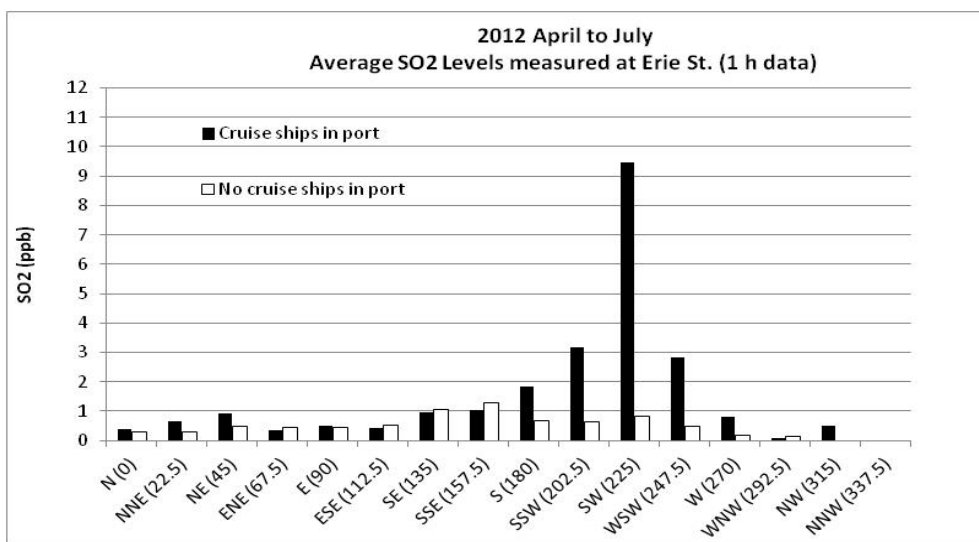
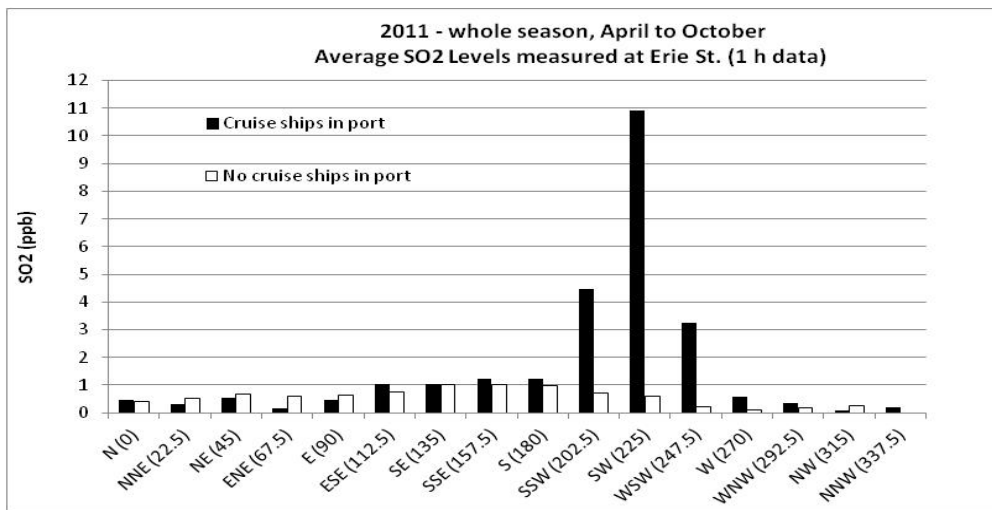
- The obvious increase in SO<sub>2</sub> levels when the ships are in port.
- The narrow wind direction range in which the Erie St. monitor will capture relevant data; essentially, only in the SSW, SW and WSW sectors, with only diffused measurements being recorded in the outer 2 sectors.
- The significant improvement, post-August 1<sup>st</sup>, in the recorded SO<sub>2</sub> levels when the wind is from the SW.
- The worsening, post-August 1<sup>st</sup>, in the recorded SO<sub>2</sub> levels when the wind is from the WSW.

As a rough estimate the WSW measurements should be multiplied by a factor of between 3 and 4 to obtain an equivalent “SW” measurement

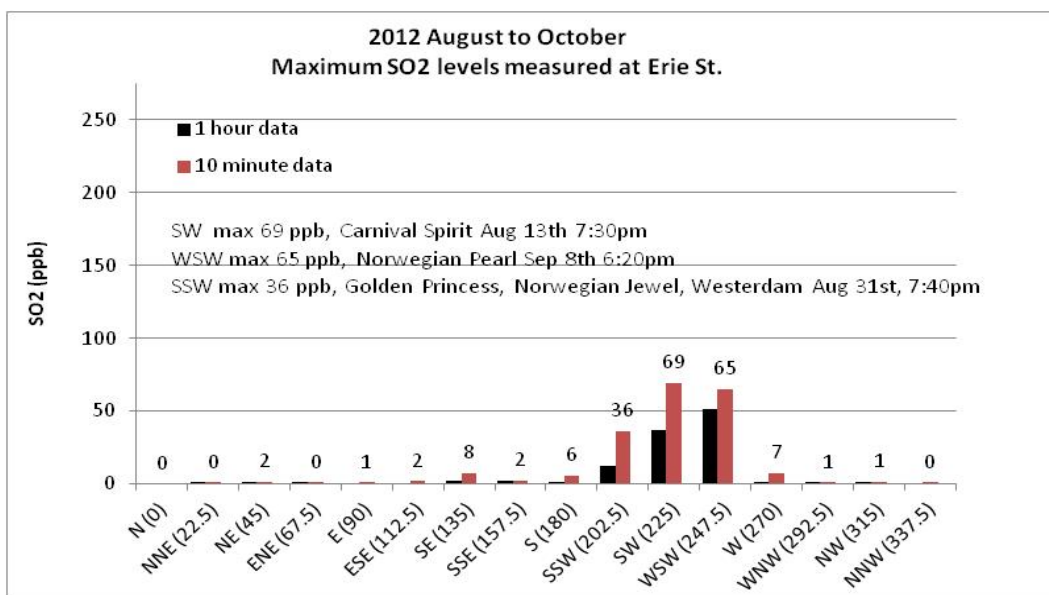
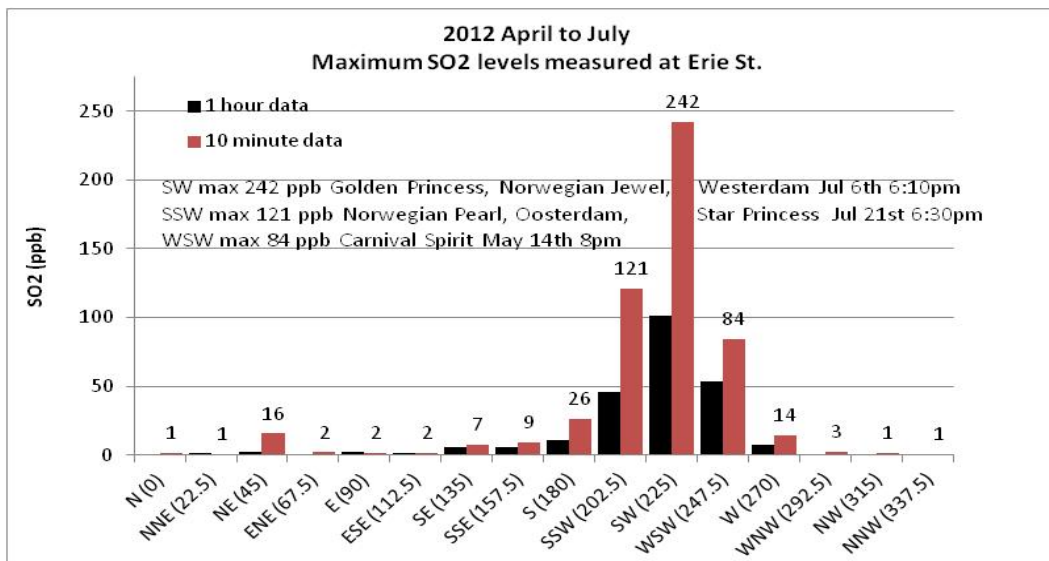
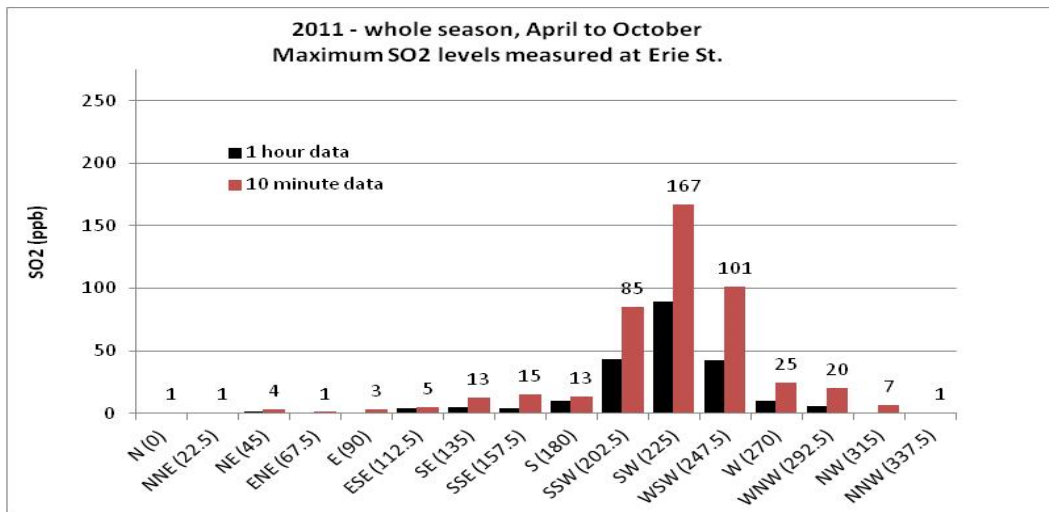
Of note for the “maximum” measurements are:

- Same comments as above regarding wind direction and the effect of cruise ships.
- The maximum recorded SO<sub>2</sub> levels have decreased, post-August 1<sup>st</sup>, for all wind directions.
- The maximum 1-hour SO<sub>2</sub> level recorded, at Erie St., during the 2011 season was 101 ppb and the maximum 10-minute level was 242 ppb.
- The ship, or ship combinations, in port when the highest SO<sub>2</sub> levels were recorded were:
  - SW wind direction: Golden Princess, Norwegian Jewel, Westerdam
  - SSW wind direction: Norwegian Pearl, Oosterdam, Star Princess
  - WSW wind direction: Carnival Spirit

The Erie St. monitor is nearly 1 km. from the Ogden Point Piers. Residents, visitors and local employees will experience higher levels of SO<sub>2</sub> at other James Bay locations.









## Comparison with same ships

Although the previous graphs show a reduction in the average SO<sub>2</sub> post-August 1<sup>st</sup> we are not comparing identical situations – wind speed and directions are different and different combinations of ships are in port.

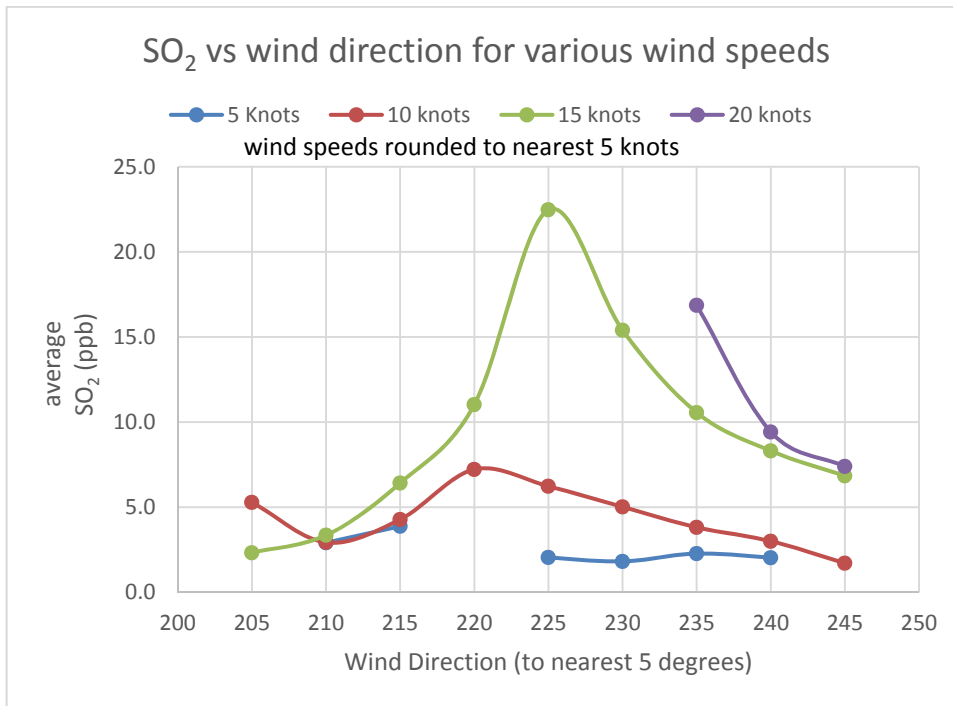
The following table compares the average SO<sub>2</sub> levels for the ship or ship combinations which were in port both pre and post-August 1<sup>st</sup> when the winds were from the SW direction (SW- 4/6, ≥2m/s). There were 47 hours post-August 1<sup>st</sup> when these conditions (same ships and wind) occurred. When the average SO<sub>2</sub> levels are calculated the difference between pre- and post-August 1<sup>st</sup> is less marked (7.7 vs. 5.7 ppb).

<b>SW Winds (4 of 6), Same Ships 2012(pre) vs. 2012 (post), using 2012 post hours</b>			
ShipNames	Hours	2012 Apr-Jul SO2 Average	2012 Aug-Oct SO2 Average
Golden Princess, Westerdam	1	16	25
Golden Princess, Norwegian Jewel, Westerdam	1	27	16
Norwegian Pearl	2	12	16
Amsterdam, Celebrity Infinity	7	16	14
Carnival Spirit	5	4	8
Disney Wonder	6	8	4
Sea Princess	3	15	3
Norwegian Pearl, Oosterdam, Star Princess	3	4	2
Norwegian Jewel	2	1	2
Westerdam	2	11	1
Rhapsody Of The Seas	6	3	1
Celebrity Infinity	8	0	0
Celebrity Infinity, Rhapsody Of The Seas	1	4	0
Totals all ships	47	7.7	5.7

## How representative are the Erie St. monitor SO<sub>2</sub> measurements of the actual ship emissions

The SO<sub>2</sub> measurements accurately record the SO<sub>2</sub> levels at the Erie St location but they are not representative of the levels experienced at locations closer to, or further away from, Ogden Point; nor are they representative of the actual ship emissions.

Only when the wind direction is in a narrow band (220° to 235°) and the wind speed >15 knots do we start to obtain measurements which are indicative of the actual ship emissions.



For this graph:

- Each 10-minute record was rounded to the nearest 5° and nearest 5 knots.
- An average value of SO<sub>2</sub> was calculated for each degree/speed value.
- If there were fewer than 30 records contributing to the average the result was omitted.

The graph indicates a relationship between SO<sub>2</sub> level detected, wind speed and wind direction.

This indicates that the monitor may not be at an optimum distance from Ogden Point to capture the highest SO<sub>2</sub> levels occurring within James Bay. Additional monitors are required to determine where the lower speed emissions touch down.

SO2 (ppb)	Wind		Ship Names
	Direction	Speed (knots)	
101	227	15	Golden Princess, Norwegian Jewel, Westerdam
76	220	14	Sea Princess
59	223	16	Sapphire Princess, Westerdam
53	243	22	Carnival Spirit
51	240	21	Norwegian Pearl, Oosterdam, Star Princess
47	228	12	Sapphire Princess, Westerdam
46	207	15	Norwegian Pearl, Oosterdam, Star Princess
45	237	23	Norwegian Pearl, Oosterdam, Star Princess
43	222	14	Disney Wonder, Sea Princess
39	233	13	Sapphire Princess, Westerdam
38	231	9	Carnival Spirit
37	236	18	Carnival Spirit
36	233	19	Golden Princess, Westerdam
35	215	16	Amsterdam, Celebrity Infinity

The Vancouver Island Health Authority publishes the following SO<sub>2</sub> Health Risk Guide on its website for the 1-hour SO<sub>2</sub> exposure levels.

**>35 ppb** - small number of persons with asthma who are very sensitive to SO<sub>2</sub> may experience symptoms. Follow Dr's advice for managing condition.

**>75 ppb** - Increasing likelihood of respiratory symptoms such as chest tightness and breathing discomfort in people with asthma. People with asthma should consider limiting outdoor exertion or reschedule when SO<sub>2</sub> concentrations are lower. Follow Dr's advice for managing condition.

**> 185 ppb** - Children, the elderly, asthmatics and people with heart and lung disease should limit exertion outdoors or reschedule when SO<sub>2</sub> concentrations are lower. Follow Dr's advice for managing condition.

The 35 ppb and 75 ppb thresholds were exceeded 14 times and 2 times respectively at the Erie St. monitoring station.

The above table shows the wind conditions when the Erie St. monitor recorded SO<sub>2</sub> levels in excess of the 35 VIHA thresholds. Note that the majority of these readings occurred when the wind conditions were within the very narrow wind band (220° to 235° and ≥15 knots); i.e., the total number of exceedences is unknown; the Erie St. monitor will only capture readings approaching those of the actual ship emissions for approximately 3% of the time that ships are in port.

## **Why is the WSW post- Aug 1st average higher than pre-Aug 1st?**

Two ship/ship combinations are associated with the high WSW post-Aug 1<sup>st</sup> average - Carnival Spirit and the Norwegian Pearl/Oosterdam/Star Princess combination.

If these two are omitted the WSW (>= 4 of 6) average drops from 5.8 ppb to 1 ppb. The average WSW SO<sub>2</sub> level when these two ship/ship combinations are in port is 10.9 ppb (see next page).

Of note is that a higher level of SO<sub>2</sub> was recorded for these two combinations when the wind was from the WSW than when it was from the SW.

Previous analysis indicates that a factor of 3 to 4 could be applied to WSW SO<sub>2</sub> measurements to allow a comparison with those from the SW. A monitor in the WSW sector would provide a more definitive factor.

<b>WSW (&gt;=4 of 6) - 1 hour SO2</b>		
ShipNames	YYMMDDHH	SO2
Norwegian Pearl, Oosterdam, Star Princess	12090819	51
Norwegian Pearl, Oosterdam, Star Princess	12090119	45.4
Carnival Spirit	12081321	27.2
Carnival Spirit	12081323	20.5
Norwegian Pearl, Oosterdam, Star Princess	12090120	19.6
Carnival Spirit	12081400	18.3
Carnival Spirit	12081322	16.3
Norwegian Pearl, Oosterdam, Star Princess	12090201	12
Carnival Spirit	12082022	11.2
Norwegian Pearl, Oosterdam, Star Princess	12090820	6.3
Norwegian Pearl, Oosterdam, Star Princess	12090200	4.6
Carnival Spirit	12082023	3.6
Carnival Spirit	12082100	3.5
Carnival Spirit	12081401	3
Norwegian Pearl, Oosterdam, Star Princess	12082519	1.7
Norwegian Pearl, Oosterdam, Star Princess	12090121	1.6
Norwegian Pearl, Oosterdam, Star Princess	12090821	1.5
Norwegian Pearl, Oosterdam, Star Princess	12090901	0.7
Carnival Spirit	12090319	0.7
Carnival Spirit	12082020	0.4
Carnival Spirit	12091020	0.3
Carnival Spirit	12081319	0.2
Carnival Spirit	12091019	0.2
<b>Average SO2</b>		<b>10.9</b>

<b>SW (&lt;= 4 of 6) , 1 hour SO2</b>		
ShipNames	YYMMDDHH	SO2
Carnival Spirit	12081320	37.1
Norwegian Pearl, Oosterdam, Star Princess	12091520	3.6
Norwegian Pearl, Oosterdam, Star Princess	12091521	1.8
Carnival Spirit	12082101	1.2
Carnival Spirit	12082722	0.8
Carnival Spirit	12090321	0.5
Carnival Spirit	12090322	0.4
Norwegian Pearl, Oosterdam, Star Princess	12092221	0.3
<b>Average SO2</b>		<b>5.7</b>

## **SO<sub>2</sub> levels associated with the various ships or ship combinations**

The following three tables compare the pre- and post-August 1<sup>st</sup> Erie St. SO<sub>2</sub> measurements associated with each ship or ship combination for the three wind directions SW, WSW and SSW. Each table is ordered in descending order of average SO<sub>2</sub>.

The blue highlight indicates ships for which measurements were available both pre- and post-August 1<sup>st</sup>. A green or red highlight indicates whether the average SO<sub>2</sub> level is better pre or post. i.e., a red highlight pre-August 1<sup>st</sup> will indicate that an improvement occurred post-August 1<sup>st</sup>.

The recorded SO<sub>2</sub> level for the SSW and WSW wind directions will be significantly less than those for the SW directions (A factor of 3 to 4 is expected); however both these tables are useful in that they identify which ships are associated with the highest SO<sub>2</sub> levels.



Pre-August 1st, hourly data, wind speed $\geq 2\text{m/s}$ , At least 4 of 6 10 min winds from SW			
Ships	Hours in Port	SO <sub>2</sub> ppb	
		Average	Maximum
Sapphire Princess, Westerdam	4	40	59
Golden Princess, Norwegian Jewel, Rhapsody Of The Seas, Westerdam	1	34	34
Golden Princess, Norwegian Jewel, Westerdam	8	27	101
Disney Wonder, Sea Princess	2	27	43
Amsterdam, Celebrity Infinity	7	16	35
Golden Princess, Westerdam	4	16	36
Sea Princess	8	15	76
Norwegian Jewel, Westerdam	2	14	26
Norwegian Pearl	2	12	14
Westerdam	2	11	20
Disney Wonder	17	8	30
Amsterdam, Celebrity Infinity, Rhapsody Of The Seas	2	8	14
Silver Shadow	3	7	11
Norwegian Pearl, Oosterdam, Star Princess	6	4	12
Norwegian Pearl, Oosterdam	1	4	4
Carnival Spirit	16	4	15
Celebrity Infinity, Rhapsody Of The Seas	5	4	11
Rhapsody Of The Seas	3	3	6
Coral Princess	1	2	2
Norwegian Jewel	4	1	2
Norwegian Jewel, Rhapsody Of The Seas	1	1	1
Disney Wonder, Statendam	1	1	1
Celebrity Infinity	6	0	1
Amsterdam, Rhapsody Of The Seas	1	0	0
	107	10.8	

Post-August 1st, hourly data, wind speed $\geq 2\text{m/s}$ , At least 4 of 6 10 min winds from SW			
Ships	Hours in Port	SO <sub>2</sub> ppb	
		Average	Maximum
Golden Princess, Westerdam	1	25	25
Golden Princess, Norwegian Jewel, Westerdam	1	16	16
Norwegian Pearl	2	16	18
Amsterdam, Celebrity Infinity	7	14	22
Amsterdam	1	10	10
Carnival Spirit	5	8	37
Disney Wonder	6	4	10
Sea Princess	3	3	5
Norwegian Pearl, Oosterdam, Star Princess	3	2	4
Norwegian Jewel	2	2	2
Westerdam	2	1	3
Rhapsody Of The Seas	6	1	4
Celebrity Millennium	1	1	1
Celebrity Infinity	8	0	1
Celebrity Infinity, Rhapsody Of The Seas	1	0	0
	49	5.7	

<b>Pre-August 1st, hourly data, wind speed <math>\geq 2\text{m/s}</math>, At least 4 of 6 10 min winds from WSW</b>			
Ships	Hours in Port	SO2 ppb	
		Average	Maximum
Sapphire Princess, Westerdam	3	11	20
Carnival Spirit	26	7	53
Golden Princess, Norwegian Jewel, Westerdam	7	7	22
Norwegian Jewel, Westerdam	2	4	6
Norwegian Pearl, Oosterdam	1	3	3
Amsterdam, Statendam	4	3	9
Norwegian Pearl	5	3	9
Celebrity Century, Norwegian Pearl	1	3	3
Norwegian Pearl, Oosterdam, Star Princess	12	3	16
Amsterdam, Celebrity Infinity	8	2	9
Norwegian Jewel	6	2	5
Golden Princess, Westerdam	3	1	3
Seven Seas Navigator	1	1	1
Rhapsody Of The Seas	3	1	2
Celebrity Infinity	3	1	1
Norwegian Jewel, Sapphire Princess	1	1	1
Sea Princess	4	0	1
Disney Wonder	12	0	1
Island Princess	8	0	1
Amsterdam, Rhapsody Of The Seas	4	0	0
	114	3.2	

<b>Post-August 1st, hourly data, wind speed <math>\geq 2\text{m/s}</math>, At least 4 of 6 10 min winds from WSW</b>			
Ships	Hours in Port	SO2 ppb	
		Average	Maximum
Norwegian Pearl, Oosterdam, Star Princess	10	14	51
Golden Princess, Westerdam	1	9	9
Carnival Spirit	13	8	27
Golden Princess, Norwegian Jewel, Westerdam	2	4	4
Sea Princess	1	1	1
Rhapsody Of The Seas	3	1	2
Sapphire Princess	2	1	1
Oosterdam	2	0	1
Celebrity Infinity	6	0	1
Amsterdam, Celebrity Infinity	3	0	0
Amsterdam, Rhapsody Of The Seas	4	0	0
	47	5.8	

<b>Pre-August 1st, hourly data, wind speed <math>\geq 2\text{m/s}</math>, At least 4 of 6 10 min winds from SSW</b>			
Ships	Hours in Port	SO2 ppb	
		Average	Maximum
Amsterdam, Celebrity Infinity	1	20	20
Norwegian Pearl, Oosterdam, Star Princess	8	11	46
Disney Wonder, Sea Princess	1	9	9
Carnival Spirit	3	6	15
Silver Shadow	2	2	4
Celebrity Infinity, Rhapsody Of The Seas	1	2	2
Rhapsody Of The Seas	6	1	5
Sea Princess	10	1	5
Amsterdam, Celebrity Infinity, Rhapsody Of The Seas	1	1	1
Norwegian Jewel, Sapphire Princess, Westerdam	1	1	1
Norwegian Jewel	1	1	1
Celebrity Infinity	1	1	1
Norwegian Pearl	3	1	1
Hanseatic	7	1	1
Golden Princess, Westerdam	1	1	1
Amsterdam, Rhapsody Of The Seas	2	0	1
Disney Wonder	1	0	0
Norwegian Jewel, Sapphire Princess	1	0	0
	51	3.4	

<b>Post-August 1st, hourly data, wind speed <math>\geq 2\text{m/s}</math>, At least 4 of 6 10 min winds from SSW</b>			
Ships	Hours in Port	SO2 ppb	
		Average	Maximum
Norwegian Jewel	2	5	9
Golden Princess, Norwegian Jewel, Westerdam	4	3	6
Celebrity Infinity, Rhapsody Of The Seas	1	2	2
Rhapsody Of The Seas	4	2	4
Golden Princess, Westerdam	2	2	2
Sea Princess	6	2	5
Disney Wonder	4	1	2
Norwegian Jewel, Seven Seas Navigator	1	0	0
	24	2.1	

## Summary of key results

The table on the following page lists many of the key results described in this report or in last year's report. This table will be updated yearly to allow trends to be detected.

Of note are:

- The higher average SO<sub>2</sub> values when the "4 of 6" 10-minute rule is applied (e.g. SW pre-Aug 1<sup>st</sup> – 10.8 vs.9.5 ppb).
- Of the 1232 hours which ships were in port only 107 + 49 = 156 (13%) occurred when the wind was from the SW (4 of 6) and  $\geq 2$  m/s.
- Post-August 1<sup>st</sup> there is a significant decrease in the number of hours the SO<sub>2</sub> level exceeded the 35 ppb guideline (1 h, 2% of time vs. 8 h, 7.5% of time).
- Almost all the exceedances when winds were from the SW were recorded when the wind speed  $\geq 10$  knots (7 and 1 vs. 8 and 1).
- The recorded SO<sub>2</sub> levels were most indicative of the actual ship emissions only 3% of the time.

2011 Apr-Oct	2012 Apr-Oct	2012 Apr-Jul	2012 Aug-Oct
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SO <sub>2</sub> ppb (speed > 2m/s)				
	Average			
SSW	4.5	2.9	3.2	2.3
SW	10.9	7.9	9.5	4.8
WSW	3.3	3.5	2.8	5
	Maximum			
SSW	43.5	46	46	12
SW	89.6	101	101	37
WSW	42.7	53	53	51
SO <sub>2</sub> ppb Average (speed > 2m/s), ">=4 of 6"				
SSW	5.3	3.0	3.4	2.1
SW	13.1	9.2	10.8	5.7
WSW	3.2	4.0	3.2	5.8
SO <sub>2</sub> ppb average (speed > 2m/s), 10 minute values				
SSW	4.8	3.0	3.3	2.3
SW	12.6	8.4	9.7	6.1
WSW	3.2	3.9	3.4	5.1
SO <sub>2</sub> ppb Maximum (speed > 2m/s), 10 minute values				
SSW	85	121	121	36
SW	167	242	242	69
WSW	101	84	84	65

Hours				
Total	1279	1232	770	462
Hours > 2m/s	926	837	587	250
%	72%	68%	76%	54%
SSW >2m/s	118 (13%)	113 (14%)	74 (13%)	39 (16%)
SW >2m/s	183 (20%)	221 (26%)	145 (25%)	76 (30%)
WSW > 2m/s	247 (27%)	203 (24%)	143 (24%)	60 (24%)

Hours for SW - where at least 4 of the 6 ten minute readings are also SW, speed > 2 m/s				
Total	120	156	107	49
SW >= 35ppb	15 (12.5%)	9 (5.8%)	8 (7.5%)	1 (2.0%)
SW >= 75ppb	2 (1.7%)	2 (1.3%)	2 (1.9%)	0 (0.0%)
As above but for wind speed >10 knots (2)				
Total	83	111	76	35
SW >=35ppb	15 (18%)	8 (7%)	7 (9%)	1 (3%)

% of time that Erie St measurements are most representative (220°-235° >=15knots)		35/1232 =3%	23/770 =3%	12/462 =3%
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### 1) Wind Speed & Direction

- Obtained from the GVHA website: <http://www.victoriaharbour.org/weather.php>
- These measurements are at 10 minute intervals and are used to create hourly averages, i.e., the wind measurements used for “10 am” is the average of all the 10-minute measurements between 9 am and 10 am.
- Only data associated with average wind speeds > 2m/s (3.9 knots) have been included in this report. At wind speeds <2m/s eddying occurs and the measured direction may not be accurate.

### 2) SO<sub>2</sub> data

- Raw hourly data has been obtained from BC Ministry of Environment website <http://www.bcairquality.ca/readings/index.html>.
- A “10am” measurement is the average of the measurements between 9am and 10am.

### 3) Ship arrivals and departures

- Scheduled ship arrival and departure times have been used in this report and were obtained from the GVHA website <http://victoriacruise.ca/page/cruise-schedule>
- For ship arrivals and departures the following are examples of the times used for linking the ship times to the **hourly** SO<sub>2</sub> and wind data:

Arrival	Leave	Data Link (arrival)	Data link (departure
1 pm	11.59 pm	1 pm	1 am next day
7:30 pm	11:59 pm	7 pm	1 am next day

Thus, in general, 0 hours have been deducted from the arrival times (30 minutes in the case of arrivals on the half hour) and 1 hour has been added to departure times. This ensures the correlation of ship arrival and departure emissions with the SO<sub>2</sub> data (A 7am measurement is for the 6am to 7am period).

For the **10-minute results** - 30 minutes have been deducted from the arrival time and 30 minutes added to the departure times.