Summary of the Health and Economic Benefits of Visibility Improvements in the Lower Fraser Valley of British Columbia

A paper presented by the BCVCC summarizing the 2013 study "Health and Economic Benefits of Visibility Improvements in the Lower Fraser Valley of British Columbia" conducted by ENVIRON EC (Canada)

20 July 2015

Introduction

Visual air quality is a concern in the Lower Fraser Valley (LFV) of British Columbia. Degraded visual air quality affects scenic views, quality of life and the economy. The British Columbia Visibility Coordinating Committee (BCVCC) was formed to develop visual air quality management tools and options. The BCVCC is comprised of Metro Vancouver, BC Ministry of Environment, the Fraser Valley Regional District, Environment Canada and Health Canada.

The principal cause of degraded visual air quality is airborne fine particulate matter ($PM_{2.5}$). In addition to reducing visibility, $PM_{2.5}$ is an air quality issue and a major contributor to negative health endpoints. The report "Health and Economic Benefits of Visibility Improvements in the Lower Fraser Valley of British Columbia-Final Report" was prepared by Environ EC (Canada) Inc. for Metro Vancouver. The study had two main purposes:

- to use the Air Quality Benefits Assessment Tool (AQBAT) to estimate the value of health benefits associated with scenarios in which $PM_{2.5}$ concentration decrease in the Lower Fraser Valley (LFV) as a result of achieving specific visibility improvement objectives; and
- to develop a simplified version of AQBAT based on a spreadsheet-based tool.

This summary focuses on the value of health benefit estimates made using AQBAT.

Method

The process AQBAT uses for estimating health benefits involves several steps. The first step is to develop scenarios that identify the concentration of $PM_{2.5}$ over a period of time, 2015-2035 in this case. The software then uses the assumed population in the study area for each year and built-in functions to determine the number of health endpoints that are predicted to arise from a particular concentration of $PM_{2.5}$. Once the quantity of each type of endpoint is calculated, they are multiplied by the unit value for that endpoint and then summed. Unit values for each endpoint are included in the AQBAT software and are expressed as dollars/case or dollars/day depending on the nature of the endpoint. For example, the unit value for each mortality is $6.8 million.

The values for most of the endpoints are determined from willingness to pay studies endorsed by Health Canada. The values don't necessarily represent cash costs of hospital visits and so on but rather what people would be willing to pay to avoid those things. The values can be discounted at an appropriate discount rate in order to calculate the present value of the benefits.

An additional feature of AQBAT is that it can incorporate variability in the number of outcomes using a Monte Carlo simulation process. Key variables such as the concentration response function and the endpoint values used in the calculations are assigned a probability distribution that AQBAT uses to run the Monte Carlo simulation. The results of the simulation show the mean and 95% confidence interval of the endpoint values for each endpoint. This is important because the randomness of these variables can lead to a range of values and the wider the range of values predicted by the model the more flexible the policies and plans related to air quality improvement should be.

The following sections provide more detail on the assumptions used in modelling the scenarios for the Lower Fraser Valley.

Scenarios

Nine visual air quality change scenarios plus the status quo scenario were modelled for the period 2015-2035. Each scenario used a change in $PM_{2.5}$ concentrations representing a visual air quality improvement (or degradation) between 2020-2035 following a status quo or “business as usual” period between 2015 and 2019. The specified changes in $PM_{2.5}$ concentrations considered in these scenarios derive from a previous study conducted by Environment Canada (So et al., 2015)[1], which established the relationship between light extinction (a metric used to quantify visibility impairment calculated from measurements of fine particle constituents and their associated scattering and absorption properties) and $PM_{2.5}$ concentrations.

Table-1 shows the average $PM_{2.5}$ concentration for each scenario, the associated visual air quality conditions relative to status quo, the difference between the status quo $PM_{2.5}$ concentration and the scenario concentration for both Metro Vancouver and the Fraser Valley Regional District. These visual air quality improvement and degradation scenarios can be categorized as: 1) objective and 2) perception-based. Objective scenarios are those that quantify visual air quality improvements using various visibility metrics such as deciviews (dv), visual range and extinction. Scenarios 1 to 4 illustrate visual air quality improvement and degradation scenarios corresponding to 1 to 3 deciviews improvement and 0.45 deciviews degradation on average visual air quality conditions, respectively. Note that each unit of deciview change corresponds to a 10% change in the light extinction and approximates the minimum perceptible change in visibility from the perspective of a human observer. Perception-based scenarios, which are illustrated by Scenarios 5 to 9, are those that model perception-based visual air quality improvements, such as increase or reduction of the number of hours in various visual air quality perception categories, where daylight hours are categorized as excellent, good, fair, poor and very poor according to the proposed Visual Air Quality-based visual air quality perception index (Sakiyama and Kellerhals, 2011)[2].

[1] So, R., Vingarzan, R., Jones, K., and Pitchford, M., 2015. Modelling of Time-Resolved Light Extinction and Its Applications to Visibility Management in the Lower Fraser Valley of British Columbia, Canada. Journal of the Air & Waste Management Association. Volume 65, Issue 6, 2015.

[2] Sakiyama, S. and Kellerhals, M., 2011. Development of a Visibility Index for the Lower Fraser Valley of British Columbia, Canada. Presented at the 2011 Conference of the Pacific North West International Section of the Air and Waste Management Association, November, 2011. Harrison Hot Springs, British Columbia, Canada. Available from : http://chapter.pnwis.org/Ch_vi/PNWIS_2011/technical_presentations.htm

Table-1 Status Quo and Forecast Concentrations

		Average $PM_{2.5}$ Concentration [μg/m³]		Difference in Average $PM_{2.5}$ Concentration (status quo – forecast) [μg/m³]	
Scenario	**Visual Air Quality Conditions (relative to status quo)**	**Metro Vancouver**	**FVRD**	**Metro Vancouver**	**FVRD**
Status Quo	Baseline	4.60	4.45	-	-
Scenario 1	1 dv improvement	3.70	3.57	-0.90	-0.88
Scenario 2	2 dv improvement	2.93	2.82	-1.67	-1.63
Scenario 3	3 dv improvement	2.29	2.19	-2.32	-2.27
Scenario 4	0.45 dv degradation	5.06	4.90	0.46	0.45
Scenario 5	50% reduction in the number of very poor hours	4.16	4.02	-0.45	-0.44
Scenario 6	10% reduction in the number of fair hours	3.92	3.78	-0.68	-0.67
Scenario 7	50% reduction in the number of poor hours	3.81	3.68	-0.79	-0.77
Scenario 8	25% increase in the number of good hours	3.68	3.55	-0.92	-0.90
Scenario 9	10% increase in the number of excellent hours	3.13	3.01	-1.48	-1.44

Health Endpoints for Each Scenario

Once the scenarios have been entered into AQBAT, the program will generate the quantity of each endpoint in each year of the study period attributable to different $PM_{2.5}$ concentrations.

The types of endpoints applicable to $PM_{2.5}$ are listed in Table-2.

Table-2 Endpoints Applicable to $PM_{2.5}$

Acute Respiratory Symptom Days	Respiratory Hospital Admissions
Asthma Symptom Days	Restricted Activity Days
Adult Chronic Bronchitis Cases	Chronic Exposure Respiratory Mortality
Child Acute Bronchitis Episodes	Chronic Exposure Cerebrovascular Mortality
Cardiac Emergency Room Visits	Chronic Exposure Ischemic Heart Disease Mortality
Respiratory Emergency Room Visits	Chronic Exposure Lung Cancer Mortality
Cardiac Hospital Admissions	

Endpoint Values

Each endpoint listed in Table-2 has a monetary value attached to it as shown in Table-3. The two exceptions are Cardiac Hospital Admissions and Respiratory Hospital Admissions. Those two endpoints are “netted” with

Emergency Room Visits. This is to prevent double counting of cases where endpoints overlap. For example, Acute Respiratory Symptom Days can progress to Restricted Activity Days so only those cases that end at Acute Respiratory Symptom Days are included in that category.

For the mortality endpoints, the value of a statistical life metric is used. The mean value in Canada for this is about $6.8 million per mortality. This value refers to the aggregated willingness to pay for a reduction in risk of mortality in the population by one. This reduction of risk could come from improved roadway design or vehicle safety for example. In this case, the reduction of risk comes from reduced $PM_{2.5}$ concentration.

Table-3 Mean Endpoint Value for all Endpoints

Endpoint	Mean Value of Endpoint (2010 $CDN)
Acute Respiratory Symptom Days	$17 (per netted symptom day)
Asthma Symptom Days	$67 (per symptom day)
Adult Chronic Bronchitis Cases	$400,000 (per case)
Child Acute Bronchitis Episodes	$400 (per episode)
Cardiac Emergency Room Visits	$5,700 (per visit)
Respiratory Emergency Room Visits	$2,600 (per visit)
Restricted Activity Days	$62 (per day)
Chronic Exposure Respiratory Mortality	$6.8 million (per mortality)
Chronic Exposure Cerebrovascular Mortality	$6.8 million (per mortality)
Chronic Exposure Ischemic Heart Disease Mortality	$6.8 million (per mortality)
Chronic Exposure Lung Cancer Mortality	$6.8 million (per mortality)

Results

The reduction in negative health outcomes and their corresponding value (undiscounted) for each scenario are presented in Tables 4 and 5.

The end results of modelling the different scenarios show a range of health benefits for the period 2015-2035. The health outcomes vary according to type. For example, for acute respiratory symptom days, the number of cases avoided range from 3.8 to 19.9 million days. For ischemic heart disease, as a result of chronic $PM_{2.5}$ exposure, the number of premature deaths avoided range from 1,032 to 5,259. The economic impacts range from $8.4 to $43 billion across all $PM_{2.5}$ mitigation scenarios assuming a 4% real discount rate. This works out to about $420 million to $2.2 billion on an annual basis assuming an even distribution of health endpoints over the 2015-2035 period. Notice that reduced mortalities comprise about 90% of the total benefit of improved air quality. Within the mortality category, about two thirds of the benefit is for reduced chronic exposure ischemic heart disease mortality.

Conclusions

Air quality has a significant effect on human health and well-being in the Lower Fraser Valley. Improved air quality can lead to large reductions in premature mortality and other negative health outcomes. The benefits, as measured by the endpoint valuations for each particular condition, are considerable (in the range of billions of dollars) and provide a starting point for determining the optimal amount of effort to reduce $PM_{2.5}$ concentrations and improve visual air quality. The benefits of aesthetic aspects of visual air quality improvement itself (tourism, real estate, etc.) are not included in these valuations, so the total benefit for the region of these improved air quality scenarios is higher than reported here.

Next steps in this work include determining the benefits to visual air quality of reduced $PM_{2.5}$ concentration and photochemical air quality modelling to estimate the temporal and geographical variability in $PM_{2.5}$ concentrations as a result of various visual air quality improvement scenarios.

Table- 4 Reduction in Health Outcomes for Visibility Improvement Scenarios 1 to 9 (business as usual through 2019). Results from AQBAT.

Endpoint	Units	Forecast Scenario								
		1	2	3	4	5	6	7	8	9
Acute Respiratory Symptom Days	Day	7,738,457	14,356,107	19,863,135	-3,955,409	3,783,138	5,851,789	6,790,397	7,910,639	12,641,833
Asthma Symptom Days	Day	139,635	259,051	358,421	-71,366	68,259	105,588	122,520	142,738	228,093
Restricted Activity Days	Day	3,230,204	5,981,188	8,262,325	-1,656,717	1,580,942	2,443,859	2,835,286	3,302,024	5,269,466
Adult Chronic Bronchitis Cases	Case	2,917	5,377	7,401	-1,508	1,431	2,210	2,562	2,981	4,743
Child Acute Bronchitis Episodes	Episode	18,058	33,036	45,185	-9,464	8,902	13,711	15,877	18,453	29,197
Cardiac Emergency Room Visits	ER Visit	512	950	1,314	-262	250	387	449	523	836
Respiratory Emergency Room Visits	ER Visit	1,316	2,442	3,379	-673	643	995	1,155	1,346	2,150
Cardiac Hospital Admissions	Hosp. Adm.	389	722	999	-199	190	294	341	398	636
Respiratory Hospital Admissions	Hosp. Adm.	261	483	669	-133	127	197	229	266	426
Chronic Exposure Respiratory Mortality	Mortality	257	475	656	-132	126	194	225	262	419
Chronic Exposure Cerebrovascular Mortality	Mortality	414	763	1,050	-214	203	313	363	423	673
Chronic Exposure Ischemic Heart Disease Mortality	Mortality	2,096	3,840	5,259	-1,095	1,032	1,590	1,842	2,142	3,392
Chronic Exposure Lung Cancer Mortality	Mortality	461	851	1,172	-238	226	350	405	472	751

Table- 5 Valuation of Reduction in Health Outcomes for Visibility Improvement Scenarios 1 to 9 (business as usual through 2019, undiscounted, $1000s of 2010 dollars). Results from AQBAT.

Endpoint	Units	Forecast Scenario								
		1	2	3	4	5	6	7	8	9
Acute Respiratory Symptom Days	$1,000s	$79,979	$148,139	$205,256	-$40,852	$39,395	$60,488	$70,401	$81,616	$130,550
Asthma Symptom Days	$1,000s	$9,304	$17,283	$23,904	-$4,764	$4,548	$7,022	$8,136	$9,524	$15,175
Restricted Activity Days	$1,000s	$199,854	$370,893	$511,494	-$102,490	$97,872	$151,306	$175,620	$204,523	$326,588
Adult Chronic Bronchitis Cases	$1,000s	$1,151,873	$2,132,132	$2,928,689	-$595,199	$564,502	$873,849	$1,013,641	$1,178,219	$1,876,589
Child Acute Bronchitis Episodes	$1,000s	$7,252	$13,256	$18,175	-$3,798	$3,578	$5,511	$6,368	$7,405	$11,737
Cardiac Emergency Room Visits	$1,000s	$2,905	$5,391	$7,456	-$1,485	$1,420	$2,196	$2,549	$2,969	$4,746
Respiratory Emergency Room Visits	$1,000s	$3,395	$6,297	$8,712	-$1,735	$1,659	$2,567	$2,978	$3,470	$5,544
Cardiac Hospital Admissions	$1,000s	$0	$0	$0	$0	$0	$0	$0	$0	$0
Respiratory Hospital Admissions	$1,000s	$0	$0	$0	$0	$0	$0	$0	$0	$0
Chronic Exposure Respiratory Mortality	$1,000s	$1,746,172	$3,231,631	$4,464,385	-$896,001	$854,780	$1,320,951	$1,533,057	$1,785,016	$2,849,179
Chronic Exposure Cerebrovascular Mortality	$1,000s	$2,817,083	$5,188,866	$7,127,349	-$1,453,757	$1,379,879	$2,130,174	$2,470,623	$2,879,129	$4,579,484
Chronic Exposure Ischemic Heart Disease Mortality	$1,000s	$14,231,654	$26,139,347	$35,787,972	-$7,450,062	$7,023,530	$10,788,013	$12,542,570	$14,588,726	$23,057,071
Chronic Exposure Lung Cancer Mortality	$1,000s	$3,143,259	$5,786,041	$7,971,598	-$1,622,933	$1,539,115	$2,375,976	$2,760,407	$3,207,771	$5,088,104
Total for All Outcomes	$1,000s	$23,392,730	$43,039,276	$59,054,991	-$12,173,075	$11,510,279	$17,718,054	$20,586,352	$23,948,367	$37,944,767