Air Quality and the Instance of Asthma in Alberta:
Is there a spatial correlation?

EAS 492: GIS For Social Sciences

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1.0 Executive Summary

It is well understood that there is a positive association between air pollution and emergency department visits for asthma in Alberta (Rowe pers. comm.). Within this context, we explored the correlation between air quality, as measured by ambient and point source parameters, and asthma related ED visit rates in Alberta. We tested the following four hypotheses:

H1: As the proximity to point sources increases, the instance of asthma increases.
H2: As ambient air quality decreases, the instance of asthma increases.
H3: Urban areas will have poorer ambient air quality than rural areas.
H4: Urban areas will have a higher rate of asthma than rural areas.

Our results indicate that:

- There is a potential relationship between the proximity to point source emissions and asthma,
- There is a potential relationship between average and maximum levels of ground level ozone and asthma, and maximum levels of sulphur dioxide and asthma, but not between the average levels of SO_2 and asthma.
- There is not a significant difference in ambient air quality between large urban areas and rural areas; and,
- Rural areas have higher rates of asthma than urban areas.

Based on our results, we recommend the following research and policy directions:

Recommendation 1: Background levels of key AAQ pollutants should be monitored.

Recommendation 2: Sensitive populations (children) should be closely studied to determine of there is a pollution threshold at which their asthma is exasperated.

Recommendation 3: Given that 15% of children do suffer asthma, more public debate should be encouraged regarding the cost-benefits of a growth economy its impacts on population health.

Recommendation 4: More research should be conducted to ensure that we are building the Ground Level Ozone Management Framework to protect against 'average' ozone levels, not just peak ozone levels.

Recommendation 5: More research should be conducted into the potential correlation between proximity to emission sources and asthma rates.

2.0 Introduction

2.1 Asthma

Asthma is a wide spread disease with rates in Alberta approaching 15% for children and 7-10% in adults (Rosychuk, et al., 2007). It is understood that asthma is caused by a combination of genetic and environmental factors, where environmental factors can act as a trigger causing an asthma attack. While indoor air quality has a direct impact on the rate of asthma, as well as the number of asthma attacks than an individual may have (USEPA), the impact of outdoor air quality on asthma is not as well understood.

2.1.2 Air Quality

The quality of the ambient air is a function of the rate pollutants are emitted into the air and the rate that the atmosphere can manage those emissions. Environmental factors such as topography and climate play an important role in controlling how quickly emissions are dispersed into the atmosphere. Air quality can be measured directly though ambient air parameters, or indirectly through the point source emission measurements. For the purposes of this study, we are interested in two types of air parameters, ambient air quality [AAQ] and point source emissions.

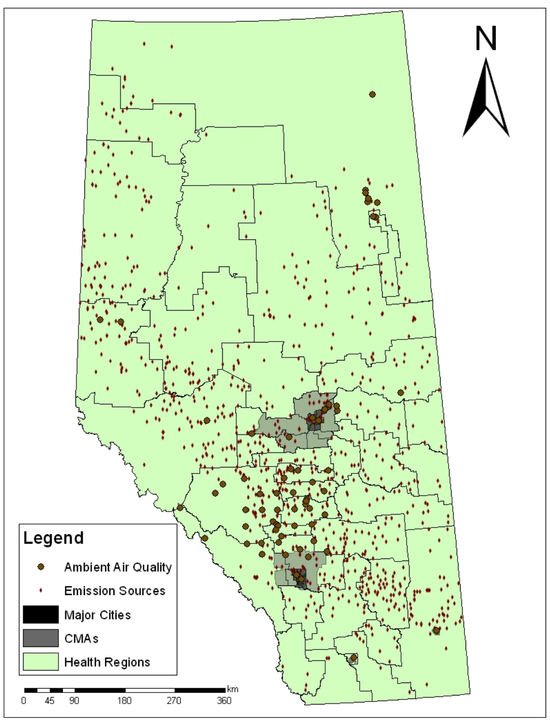


Figure 1: Emission, Ambient Air Quality and Health Region Features

2.1.2.1 Ambient Air Quality

The quality of the ambient air is a function of the dispersion of industrial emissions. AAQ is measured through the use of either continuous monitoring or passive monitoring. Continuous monitoring occurs where a small volume of air is pulled through an analyzer that tests for a number of parameters on a regular basis (i.e., per minute, hour or day). Passive air quality monitors rely on a reaction between a reagent and the parameter being test in the ambient air. As a result, passive monitors produce an averaged ambient air quality number based on the length of time the monitor was exposed to the ambient air (i.e. one week or month).

AAQ parameters include substances emitted into the ambient air by industrial facilities, substances emitted by non-point sources such as vehicles, and substances that form as a result of a chemical reaction in the ambient air. The AAQ parameters that we are interested in for the purposes of this study include the primary pollutants particulate matter [PM], oxides of nitrogen [NO_x], and sulphur dioxide (SO_2); and the secondary pollutant ground level ozone [O_3]. O_3 is considered a secondary pollutant because it occurs as a result of a chemical reaction in the atmosphere between NO_x, sunlight and heat.

2.1.2.2 Industrial Emissions

Point source emissions are those substances originating from large industrial facilities such as the oil and gas upgraders found in Fort Saskatchewan and coal fired electrical generation plants found in the Lake Wabamun area west of Edmonton. The measurement of point source emissions is relatively straightforward in that a monitor is placed into the emissions stream of the facility. This monitor measures the amount of a specific pollutant as it is emitted through the stack and into the atmosphere.

The point source parameters that we are interested in for the purposes of this study are SO_2, NO_x and PM.

2.2.3 Scope and Context

Poor outdoor air quality is a determinant in the number of visits that an Alberta Emergency Department [ED] receives for asthma (Rosychuk, et al., 2007, Villeneuve 2007). Within this context, Alberta has experienced unprecedented population and industrial growth over the last six years (Statistics Canada, 2006). One of the many issues associated with the increase of industrial output and population growth is the potential of poor air quality outcomes in urban and rural areas.

Alberta Environments' report on their Particulate Matter and Ozone Management Framework (Alberta Environment, 2005) indicates that the levels of PM and O_3 found in the ambient air of Edmonton, Calgary and Red Deer are of concern in that they might negatively impact human health. The United Stated Environmental Protection Agency has identified Particulate Matter, Ozone, Oxides of Nitrogen and Sulphur Dioxide as pollutants that can aggravate asthma (USEPA). Within this context, we are interested in exploring the extent of the association between industrial emissions, AAQ and asthma in Alberta.

Our project is unique in that other researchers (Rosychuk, et al., 2007, Villeneuve 2007) have examined event-based correlations between air quality and asthma in Alberta. These studies have looked at 'spikes' in Alberta emergency room admittance, and then back cast the ambient air quality to look for a correlation that spike and AAQ. We are examining a broader spatial and temporal scope, with the intent of understanding the correlation between industrial emissions, AAQ values and the instance of asthma in Alberta.

3.0 Hypothesis

It is well understood that there is a positive association between air pollution and emergency department visits for asthma in Alberta (Rowe pers. comm.). Within this context, we are interested in exploring the correlation between air quality, as measured by ambient and point source parameters, and asthma related ED visit rates in Alberta. For the purposes of our study, we will be testing the following four hypotheses:

H1: As the proximity to point sources increases, the instance of asthma increases.
H2: As ambient air quality decreases, the instance of asthma increases.
H3: Urban areas will have poorer ambient air quality than rural areas.
H4: Urban areas will have a higher rate of asthma than rural areas.

4.0 Methods

The appropriate data were collected, manipulated and analyzed using Microsoft Excel and the GIS programs ESRI ArcMap 9.0, ESRI ArcCatalog, GeoDa 9.0, and MapInfo.

4.1 Collecting the Data

The first step in testing our four hypotheses was to identify and gather the appropriate data. Data sources, characteristics, and attributes are described in Figure 2.

Figure 2: Data Sources and Characteristics.

Data	Source	Format and attributes
Ambient Air Quality	The CASA Data Warehouse	Microsoft Excel file. • Maximum and average AAQ measurements for: o Particulate Matter o Oxides of Nitrogen o Ground Level O_3 o Sulphur Dioxide For the fiscal year of 2005 • Lat. / Long. coordinates
Point Source Emissions	National Pollutant Release Inventory	Microsoft Excel file. • Total annual emissions by parameter o Particulate Matter o Oxides of Nitrogen o Ground Level O_3 o Sulphur Dioxide For the calendar year of 2005 • Lat. / Long. coordinates
Asthma Data	Dr. Brian Rowe, University of Alberta	Microsoft Excel file. • Emergency Department asthma visits • Population For the fiscal year of 2005
Health Region Data	Erik Ellehoj, Capital Health Region	MapInfo file. 2 dimensional polygons depicting the 7 health regions and 52 sub-regions in Alberta.

4.2 Manipulating the Data

Before beginning the analysis, we first needed to manipulate our data so it could be analyzed entirely on the GIS programs ESRI ArcMap 9.0 and Geoda 9.5. Three feature classes were created and stored as shape files:

- **AAQ Stations:** With attribute values for each of its four pollution parameters
- **Point Source emissions:** With attribute values for each of its three pollution parameters
- **Health Subregions:** With an ID and an ED visit rate attribute.

4.2.1 Creating the *AAQ Stations* and *Point Source emissions* feature classes

Our point source emissions and AAQ data sets existed in Microsoft Excel files, and were converted into dBase files through Excel, and then shape files through the GIS program ArcCatalog.

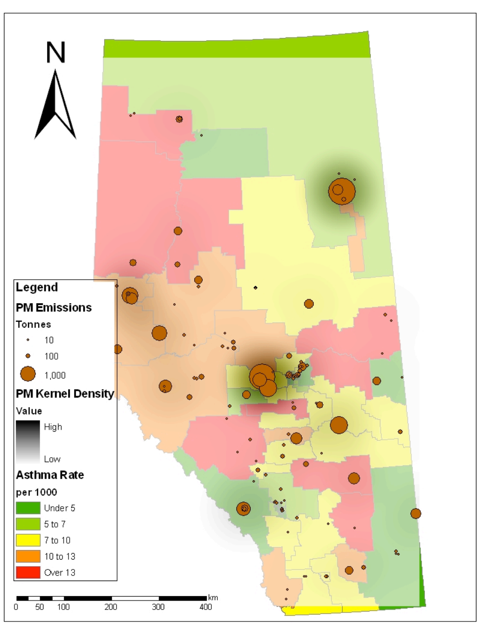
4.2.2 Creating the *Health Subregions* feature class

Our Health region file existed in a format only readable by another GIS program – MapInfo, and was converted to an ESRI-readable file though the MapInfo tool *Universal Translator*. Next, our Asthma Data was converted from Excel to dBase, and joined to the newly created *Health Subregions*. Finally, a new attribute: ED visit rates per 1000 people, was calculated in the field calculator dividing total ED visits by population and multiplying by 1000.

4.2.3 Projecting the feature classes on a metric coordinate system

We now had the three ESRI-readable shape files necessary to conduct our analysis, but these files were projected onto decimal degree coordinate systems, and had to be projected onto a metric UTM coordinate system using ArcCatalog's tool *Projections and Transformations*.

Figure 3: PM Kernel Density and Asthma Rates



4.3 Analysis

With the data collected, manipulated and projected onto a metric coordinate system, we could now begin our analysis.

4.3.1 Testing Hypothesis One: Asthma rates and Proximity to Emission Sources

With the data collected and manipulated, we could now begin testing our hypotheses. To test our first hypothesis we first needed to create kernel density rasters for each pollutant. It was determined this kernel density raster needed

For each point source parameter, a kernel density raster with a radius of 100 km and a spatial resolution of 1 km^2 was created using ArcMap's *Kernel Density* tool. The maximum kernel density values for each *Health Subregion* polygon were then calculated and joined to the *Health Subregion* feature class using the *Zonal Statistics Tool*.

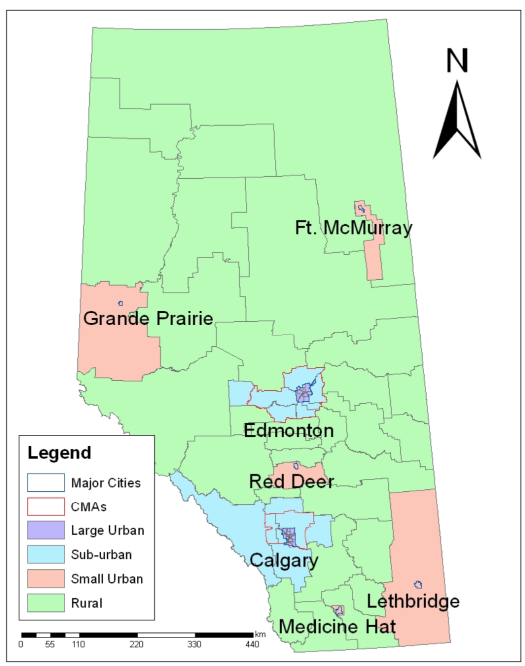
4.4 Testing Hypothesis Two: Asthma Rates and Interpolated Ambient Air Quality

To test our second hypothesis, ambient air quality values for each parameter were interpolated across Alberta. First, stations that did not record data for a certain parameters, were excluded from the analysis for said parameter. In order to do this, AAQ stations which were recording that parameter, and thus did not have zero for a value, were selected, and exported to create a new feature class. This process was repeated for each parameter necessary, and thus five new feature classes were created: *NOX*, *SO2, PM, OzoneMax, OzoneMean*. It was then determined that since too few AAQ stations were measuring PM and NOX (roughly 15 across all of Alberta), an effective interpolation could not be generated. This left us with for four AAQ values to interpolate: Maximum SO2, Average SO2, Maximum Ozone and Average Ozone.

These interpolations were performed using the Inverse Distance Weighting method through the ArcMap's *IDW* tool. They incorporated a maximum of 6 points, with weights decaying to the 2^{nd} power. In order to avoid interpolating values at points too far away from ambient air quality stations, a maximum radius was set at 50 km. The raster output has a spatial resolution of 1 km^2. The maximum interpolated AAQ values for each *Health Subregion* polygon were then calculated and joined to the *Health Subregion* feature class using the *Zonal Statistics tool*.

4.5 Testing Hypothesis Three: Urbanization and Ambient Air Quality

Figure 4: Urbanization Classifications



To test our third hypothesis, we first needed to classify *Health Subregion* features by urbanization. The 2006 Canadian census found that Alberta is home to two centers with roughly 1 million residents: Edmonton and Calgary; five centers with between 40,000 and 100,000 residents: Ft. McMurray, Red Deer, Medicine Hat, Lethbridge and Grande Prairie); and no other centers with more than 20,000 residents. With this knowledge, four categories of urbanization were delineated:

> **Large Urban:** Polygons located within municipalities with 500,000 or more residents, specifically Edmonton and Calgary.

Sub-urban: Polygons located outside of the municipalities with 500,000 or more residents, but inside their Census Metropolitan Areas (CMAs)

Small Urban: Polygons outside of the CMAs of Large Urban municipalities, and within which lie municipalities with between 40,000 and 500,000 residents.

Rural: Polygons outside of the CMAs of Large Urban municipalities, and within which lay no municipalities with more than 40,000 residents.

Maximum interpolated AAQ values were averaged for each category and AAQ parameter. These values were then compared with one another between each of urbanization.

4.6 Testing Hypothesis Four: Urbanization and Asthma Rates

To test our final hypotheses, asthma rates across an entire class were calculated. This analysis was performed though Microsoft Excel by totaling asthma instances and populations and calculation an annual rate per 1000 people. The values for each class of urbanization were then compared.

4.7 Completing the Tests for Hypotheses One and Two: Performing Regression analyses

After the procedures outlined in sections 4.1 through 4.4 were performed, the *Health Subregions* feature class incorporated seven new attributes: The maximum kernel density values located within each polygon feature for SO2, PM and NOX emissions, and the maximum interpolated values for average and maximum ambient SO2, and average and ambient ground level Ozone. To complete the tests for our first two hypotheses, regression analyses were performed for each of these seven attributes though GeoDa 9.5. In order to further our understanding, scatterplot charts were created.

4.7.1 Performing regression analyses for Edmonton and Calgary only

Considerable bias in the Asthma data may have been introduced because of the availability of alternative sources of care other than admittance to the ED as well as patterns of medical practice in non-urban settings. (Rosychuk, et al., 2007) The large discrepancy of ED visit rates for asthma between Large Urban (4.3 per 1000) and Rural (11.9 per 1000) subregions, may reflect the existence of such a bias. In an attempt to eliminate this bias, it was determined that the regression analysis should be performed for Edmonton and Calgary only. In order to do this, a new feature class containing only health subregions located within the municipalities of Edmonton and Calgary were created by selecting features classified as Large Urban, and exporting them into a new feature class. The regressions were performed, and scatterplot graphs created, using this new feature class.

5.0 Results and Discussion (5 pages)

5.1 Introduction

For the purposes of this study we attempted to find a correlation between [AAQ] and proximity to point source emission parameters, and the rate and instance of asthma in Alberta. To that end, the following 4 hypothesis were tested using the ArcGIS and GeoDa software:

- **H1:** As the proximity to point sources increases, the instance of asthma increases.
- **H2:** As ambient air quality decreases, the instance of asthma increases.
- **H3:** Urban areas will have poorer ambient air quality than rural areas.
- **H4:** Urban areas will have a higher rate of asthma than rural areas.

5.2 Results

5.2.1 Hypothesis One: "As the proximity to point sources increases, the instance of asthma increases."

For the purpose of this study, point source emissions are defined as those facilities emitting more than one tonne of a parameter per annum. Through the methods outlined in section 4.3.1, we were able to assess the relationship between proximity to point source emissions and the instance of asthma for SO2, PM and NOx.

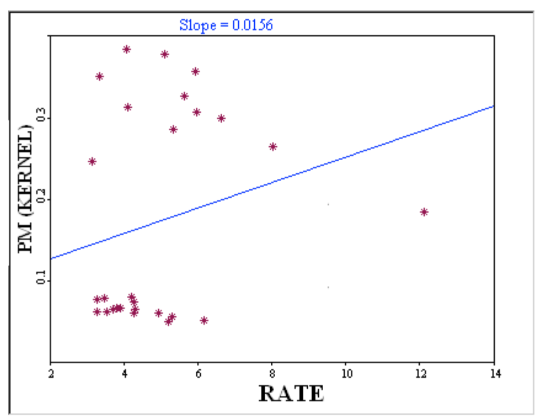
5.2.1.1 Results for the analysis encompassing the whole of Alberta

The analysis performed for the whole of Alberta was deemed inadequate due to the perceived urban/rural bias.

5.2.1.2 Results for the analysis encompassing Edmonton and Calgary only

SO2: The regression analysis indicates a positive correlation between the proximity to SO2 emissions and instances of asthma. However, this regression also indicated that the probability this correlation is due to chance is 59.7%. As such, we could not positively verify our first hypothesis for SO2.

Figure 5: PM Kernel vs. Rate Scatterplot



PM: The regression analysis indicates a positive correlation between the proximity to PM emissions and instances of asthma. However, this regression also indicated that the probability this correlation is due to chance is 25.5%. As such, we could not positively verify our first hypothesis for [PM].

NOx: The regression analysis indicates a positive correlation between the proximity to NOx emissions and instances of asthma. However, this regression also indicated that the probability this correlation is due to chance is 32.1%. As such, we could not positively verify our first hypothesis for SO2.

5.2.2 Hypothesis Two: As ambient air quality decreases, the instance of asthma increases.

The monitoring of the ambient air tends to occur where there are people, within airsheds. As such, we were able to obtain an adequate number of AAQ SO2 and O_3 data points. By interpolating these ambient parameters, we were able to generate regression analyses to test H2 for each parameter.

5.2.1.1 Results for the analysis encompassing the whole of Alberta

The analysis performed for the whole of Alberta was deemed inadequate due to the perceived urban/rural bias of the asthma data.

5.2.1.2 Results for the analysis encompassing Edmonton and Calgary only

SO2 Maximum: The regression analysis of the interpolated maximum values for SO2 found in each urban polygon indicates that there is a positive relationship between maximum SO2 values and the instance of asthma, and that the probability this correlation is due to chance is 0.03%. Thus it appears we can positively verify our second hypothesis for maximum SO2.

SO2 Average: The regression analysis of the interpolated average values for [SO2] found in each urban polygon indicate there is a negative relationship between average SO2 values and the instance of asthma. Thus, we could not positively verify our second hypotheses for average SO2.

O3 Maximum: The regression analysis of the interpolated maximum values for O_3 found in each urban polygon indicate there is a positive relationship between maximum O3 and the instance of asthma, but that the probability this correlation was due to chance is 18.3%. Thus, we could not positively verify our second hypotheses. Thus we could not positively verify our second hypothesis for maximum O3.

O3 Average: As with the interpolated maximum ozone values, there is a positive relationship between interpolated average ozone values and the instance of asthma, but again, the probability this correlation was due to chance is 20.0%. Thus we could not positively verify our second hypothesis for average O3.

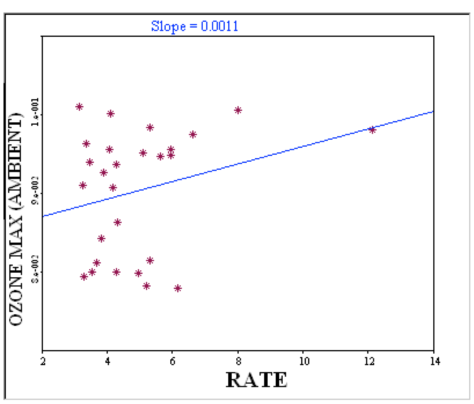


Figure 6: Maximum Ambient O_3 vs. Rate

5.2.3 Hypothesis Three: Urban areas will have poorer ambient air quality than rural areas.

The results for testing H3 can be found in Figure 7. The data used to populate this figure were obtained using the methods described in section 4.5. This data indicates that there is not a large difference in AAQ along the urbanization continuum. For instance, the maximum O3 values range from 0.092 for Edmonton and Calgary to 0.0829 for rural.

Average O3 values range around 0.03, while maximum SO2 values increase in the smaller communities. As such, we were unable to positively verify our third hypothesis.

Figure 7: Ambient Air Quality Parameters and Urban Classification

Parameter	Large Urban	Suburban	Small Urban	Rural
O3 Maximum (ug/m3)	0.0902	0.0941	0.0788	0.0829
O3 Average (ug/m3)	0.0202	0.029	0.03	0.0315
SO2 Maximum (ppm)	0.0831	0.072	0.116	0.12
SO2 Average (ppm)	0.00224	0.0299	0.00086	0.00144

5.2.4 Hypothesis Four: Urban areas will have a higher rate of asthma than rural areas.

Asthma rates along the urban continuum can be found in Figure 8.

Figure 8: Asthma Rates for Urban to Rural Classification

Parameter	Large Urban	Suburban	Small Urban	Rural
Asthma rate (per 1000)	4.73	7.20	8.11	11.19

Our fourth hypothesis could not be positively verified. However, due to the bias in the asthma data, we believe this potential correlation warrants further investigation.

5.3 Discussion

The intent of this study is to further the understanding of the relationship between air quality and asthma. To that end we devised a study that tests AAQ and emissions data for Alberta against asthma rates. Our findings indicate that:

- There is a potential relationship between the proximity to point source emissions and asthma,
- There is a potential relationship between average and maximum levels of ground level ozone and asthma, and maximum levels of sulphur dioxide and asthma, but not between the average levels of SO2 and asthma.
- There is not a significant difference in ambient air quality between large urban areas and rural areas; and,
- Rural areas have higher rates of asthma than urban areas. As we discussed in section 4.7.1, we believe this potential correlation warrants further investigation due to the bias identified in the asthma dataset.

Our analysis was limited by the omission of climate or atmospheric variables in the data analysis. The ability of the atmosphere to disperse industrial emissions is a determining factor in the exposure of humans to those emissions. The atmospheric dispersion of industrial emissions may explain the weakness of the relationship between those emissions and asthma, in that the density kernels created in section 4.3.1 is not representative of true emissions exposure.

Ground level ozone is a secondary pollutant formed as a result of a reaction between oxides of nitrogen, sunlight and heat. O_3 is most commonly found in urban settings where NO_X is produced by non-point source vehicle emissions. As documented in Alberta Environment's report of Particulate Matter and Ozone (Alberta Environment, 2005), the CMA's of Edmonton and Calgary do have elevated levels of these pollutants. Our study indicates that there is a correlation between O_3 and asthma in large urban settings for both maximum and average O_3 levels.

It is surprising that there is not a noticeable difference between rural and urban air quality. Because the AAQ monitoring network is denser where people live, and the monitors themselves are placed where AAQ tends to be poor, the lack of a gradient from large urban centers to rural environments may be more a reflection of the network not monitoring good air quality, than the observation that rural and urban areas have comparable air quality.

As discussed in Section 4.7.1 of this report, there is a bias in the asthma data based on how it was gathered through ED admissions. While the data clearly suggests that rural areas have a higher rate of asthma as compared to urban areas.

In Alberta and most other jurisdictions, ambient air quality is managed by objectives or guidelines. An air quality objective defines the 'threshold' where air is considered unclean or unsafe to human or ecosystem populations. Although the maximum level of SO2 found in the ambient air is below the Alberta Ambient Air Quality Objective of .057

parts per million, we are still seeing a potential correlation between spikes in ambient SO2, proximity to SO2 point source emissions, and asthma.

The fact that Alberta's ambient air quality objectives are not protecting the entire population of Alberta indicates that, as a society, we are willing to sacrifice the health of vulnerable populations for economic gain. This specific issue has not been debated within the broad context of industrial, urban or economic growth.

6.0 Conclusion

While we were disappointed not to observe more significant findings from this research, we are able to draw some broad conclusions regarding future work and potential ambient air quality policy implications.

Despite a growing industrial base and urban populations, the air in Alberta seems to be relatively clean with the exception of ground level ozone problems in the urban regions. While we did observe that there is not a qualitative difference between urban and rural air quality for the parameters measured, we feel that this could in fact be due to a bias in the air that is monitored. The ambient air that is being monitored tends to be the air closest to point and non-point source emissions.

Recommendation 1: Background levels of key AAQ pollutants should be monitored.

Acknowledging the bias in the asthma rates for Alberta, we were surprised that rural populations tend to have higher rates of asthma considering that there was not a qualitative difference in the AAQ of rural versus urban air. This suggests that there are sensitive populations that are vulnerable to levels of AAQ pollutants below the established AAQ Objectives.

Recommendation 2: Sensitive populations (children) should be closely studied to determine of there is a pollution threshold at which their asthma is exasperated.

Recommendation 3: Given that 15% of children do suffer asthma, more public debate should be encouraged regarding the cost-benefits of a growth economy its impacts on population health.

Because we saw a positive result while correlating maximum and average AAQ levels of ground level ozone, we feel that there is some further question regarding the Ground Level Ozone Management Framework.

Recommendation 4: More research should be conducted to ensure that we are building the Ground Level Ozone Management Framework to protect against 'average' ozone levels, not just peak ozone levels.

Finally, our work was limited by several factors that suggest more research could be applied to our thesis of the correlation between AAQ and asthma.

Recommendation 5: More research should be conducted into the potential correlation between proximity to emission sources and asthma rates.

6.1 Acknowledgements

We gratefully acknowledge the patient assistance that we received from Dr. Brian Rowe and Dr. Rhonda Rosychuk for providing advice and the asthma data for Alberta. Janine Ross and Andrew Clayton provided support in obtaining the Ambient Air Quality Data for Alberta, and Mauricio Castillo and Dr. Arie Croitoru provided technical advice on our analysis.

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