Exploring the Association between Low Birth Weight and Exposure to Air Pollution in Massachusetts: Air Pollution Concentration Monitoring

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Summary

Low birth weight (LBW) is closely related with fetal and neonatal mortality and morbidity, inhibited growth and cognitive development, and chronic diseases later in life. Thus, we propose the project "Exploring the Association between Low Birth Weight and Exposure to Air Pollution in Massachusetts" as a case study on the association between LBW and six common air pollutants on EPA's National Ambient Air Quality Standards (NAAQS) in Massachusetts. This is also our Master's final thesis.

We have obtained the LBW data from the Massachusetts Department of Public Health (MassDPH). It is available down to the census block level and recorded 623,844 births from 2000 to 2007. The air quality data, nevertheless, has been a challenging problem for us. The EPA air pollution models only provided the data of Diesel Particulate Matter (DPM), ozone and lead, while only 30 monitoring sites were unevenly distributed in Massachusetts. It is not viable to conduct analysis based on these data.

Therefore, we propose this project to obtain air monitoring observations covering Massachusetts completely, as well as use these observations to generate an air pollutant concentration surface for each chemical. In this project, we will collect the air pollutant data of Carbon Monoxide (CO), Nitrogen Dioxide (NO2), Particulate Matter (PM10), Particulate Matter (PM2.5) and Sulfur Dioxide (SO2) at 120 monitoring locations in Massachusetts. We will use a GPS unit to locate these locations and obtain the concentration of these pollutants at every location. For each chemical, a concentration surface will be generated based on observations at these 120 locations. This surface will enable us to explore the amount of pollutant that each birth was exposed to and its relationship with birth weight. Two rarely used statistics, Geographically Weighted Odds Ratio and Geographically Weighted Logistic Regression will be used to explore this relationship and characterize the spatial heterogeneity of this relationship.

To successfully conduct the field work, we would need the funds for equipment, travel, and food. The total anticipated budget is $XXXX.

Title

Exploring the Association between Low Birth Weight and Exposure to Air Pollution in Massachusetts: Air Pollution Concentration Monitoring

Background

Low birth weight (LBW) is closely related with fetal and neonatal mortality and morbidity, inhibited growth and cognitive development, and chronic diseases later in life. Various studies have indicated the association between low birth weight and air pollution (Ha et al. 2001; Dugandzic et al. 2006; Slama et al. 2007; Aguilera et al. 2009). We proposed a project "Exploring the Association between Low Birth Weight and Exposure to Air Pollution in Massachusetts" as a case study on the association between LBW and six pollutants (CO, lead, NO_2, PM_{10}, $PM_{2.5}$, O_3 and SO_2) on EPA's National Ambient Air Quality Standards (NAAQS) in Massachusetts. This is also our Master's final thesis.

This project has been going for one year. In the past year, we completed both descriptive and multivariate statistic analysis of the LBW dataset from the Massachusetts Department of Public Health (MassDPH). This dataset recorded 623,844 births from 2000 to 2007 with variables including infant's birth weight, sex and plurality as well as the mother's age, marital status, race, education, gestational age and diseases. We also applied a statistic, Geographically Weighted Odds Ratio (GWOR), to characterize the spatial heterogeneity of the association between LBW and air pollutant concentration. Those results were summarized in our paper "Exploring the Association between Low Birth Weight and Exposure to Lead Using Geographically Weighted Odds Ratio" and presented in The 2011 New England - Saint Lawrence Valley Geographical Society (NESTVAL) Conference (October 14th-15th, Montreal, Quebec, Canada).

The biggest problem in this project is the lack of air pollutant concentration monitoring data in Massachusetts. In previous studies, two approaches have been employed to obtain the air pollutant concentration or exposure data within an area: modeling the dispersion from pollutant sources, or interpolating a smooth surface based on point observations. Two results of the former provided by the EPA are the National Air Toxics Assessment (NATA) and Risk-Screening Environmental Indicators (RSEI) model. Among 6 chemicals, only Diesel Particulate Matter (DPM) is available in the NATA, and ozone and lead are available in the RSEI. Their concentration values are estimated based on modeling instead of direct observations. The latter approach generates a smooth surface of air pollution concentration based on observations. However, currently there are only 30 unevenly located monitoring sites in Massachusetts (figure 1). This number is insufficient for generation of a concentration surface characterizing the spatial heterogeneity within the state.

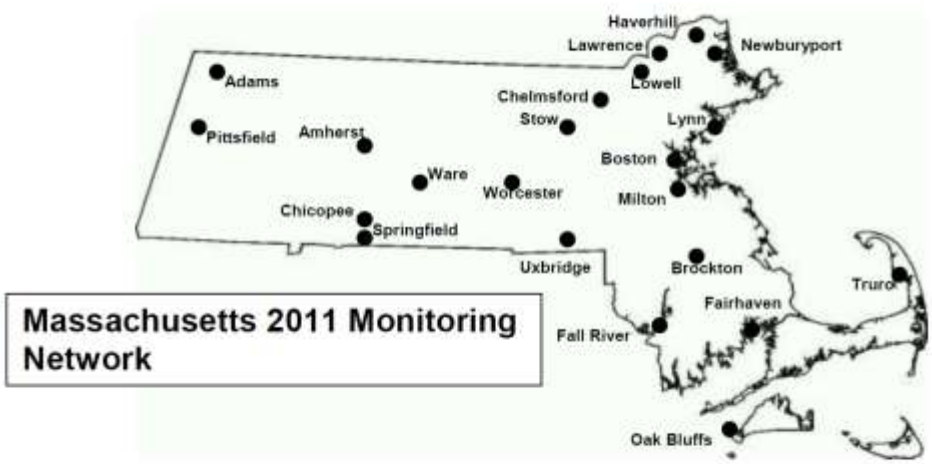

Figure 1. Air monitoring network in Massachusetts

Therefore, we realized that collecting air pollution concentration data from the field is needed. We propose this project to obtain observations using a mobile monitoring station, which is composed of chemical monitoring equipment and a GPS unit installed on a car. These observations will be employed to interpolate an air pollutant concentration surface for each chemical.

Objectives

The primary objective of this project is to obtain the concentration observations of four of the six chemicals that are listed on EPA's NAAQS: Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Particulate Matter (PM_{10} and $PM_{2.5}$) and Sulfur Dioxide (SO_2). As mentioned above, EPA's air pollution models only estimate the concentrations of Diesel Particulate Matter (DPM), lead and O_3. Most of the EPA Air monitoring sites provide data for all of these four chemicals, whereas the number of existing monitoring stations is not enough to interpolate a concentration surface, by which the concentration at any location in the state could be estimated. Only by collecting data from the field could we obtain more observations to generate the surface. Those observations will be obtained at the locations we choose, which are systematically distributed within the state. A concentration surface will be produced using interpolation tools in GIS for each chemical we explore. Using this surface, we will be able to identify the amount of chemical concentration that each baby born in Massachusetts in 2000-2007 was exposed to, as well as explore the association between LBW and air pollution in our study area.

Study Process

In this study, we will attain our objective with the following steps:

1. Design the sampling structure: we plan to collect the air pollutant concentration data at 120 locations within Massachusetts. These locations will be evenly distributed across the state and are able to characterize the spatial variation of pollution concentration. The Geospatial Modelling Environment tool (previously named Hawth's Tool), an add-on toolbox of ArcMap, will be used to distributed these monitoring locations systematically within the state. In addition to their overall distribution, the proximity to existing monitoring stations and the accessibility of each location will also be considered. Therefore, these systematically generated locations will also be manually adjusted to meet these criteria.
2. Purchase and prepare equipment for field trips: the concentrations of four chemicals will be detected by three types of monitors (table 1). DustScan Scout 3020 nephelometer is available from the IDCE Department at Clark, while Dräger Pac 3500 and Dräger Pac 7000 need to be purchased. In addition to air monitors, a laptop and Garmin GPS unit (provided by the IDCE Department) will also be employed to precisely locate monitoring locations.

Table 1. Monitors and detected chemicals

Monitor	Chemicals
DustScan Scout 3020 nephelometer	$PM_{2.5}$, PM_{10}
Dräger Pac 3500	CO
Dräger Pac 7000	NO_2, SO_2 (one device for each)

3. Conduct a test field trip: before going to the actual field trip, we will conduct at least one test field trip. It only covers a smaller area within a shorter period of time. By doing this, we would like to ensure that our equipment will function normally when we actually start our field work.
4. Work in the field: we plan to conduct nine field trips. During each field session, we will drive a car with equipment to visit all the locations we selected in the first step. 40 monitoring locations will be visited in one day. The entire Massachusetts is anticipated to be covered in three days. In other words, all monitoring locations will be visited three times in these nine field trips. Considering the variation of air pollutant concentration within a day, for any location, these three visits will be conducted at different times of the day. This strategy enables us to calculate a general amount of concentration for each monitoring location.
5. Process and interpolate field data: our field data will be reviewed and generalized. These point observations will then be interpolated using kriging tools in Geospatial Analyst in ArcGIS to generate a smooth air pollution concentration surface.
6. Explore the relationship between LBW and pollutants: when the surface is generated, we can find the correspondent air pollution exposure value of every birth case in Massachusetts. Two statistic methods we improved, Geographically Weighted Odds Ratio (GWOR) and Geographically

Weighted Logistic Regression (GWLR), will be used to explore the relationship between LBW and these pollutants.

Both Chia-Rung Yang and Hong Xia will be participating throughout this study process. When analyzing the data, Yang will focus on methodology and connection with theories, while Hong will focus on data management and processing. During the field trips, each of us will rotate to be the driver; meanwhile, the other will be the trip guide.

Anticipated Results

With this study process, we will be able to explore the association between LBW and air pollutants. It will provide the maps of air pollutant concentrations in Massachusetts, the evidence of air pollution's effect on human health, and the analysis of spatial variation of this effect across our study area.

Academic Context

Our study demonstrates its importance in terms of its study area, analysis method, and relevancy to policy. First, it covers the area of a state completely and contains both urban and rural areas. Among the ten studies using air monitoring data we reviewed (table 2), six of them were conducted within urban areas. Only one of them was conducted at the state and province level (Dugandzic et al., 2006). None of them covered the area of Massachusetts outside Boston. We found that most of them utilized the existing monitoring data within study areas. Generally those monitoring data have a more even and dense coverage within cities. In our study, instead, the field work enables us to include the rural areas in Massachusetts. The field experience and data we obtain will be valuable for related studies in the future.

Table 2. Study areas of previous research

Level of Study Area	Studies
National	US (Liao et al., 2006)
State and Province	Nova Scotia, Canada (Dugandzic et al., 2006)
County	Shelby County, Tennessee, US (Ozdenerol, 2005) San Diego County, California, US (Ross et al., 2006)
Urban Area	Six Cities in the Northeastern US (Maisonet et al., 2001) Sao Paulo, Brazil (Gouveia et al., 2004) Munich, Germany (Slama et al., 2007) Vancouver, British Columbia, Canada (Nethery et al., 2007) Vancouver, British Columbia, Canada (Brauer et al., 2008) Sabadell City, Spain (Aguilera et al., 2009)

Second, we applied two statistics that are rarely used before. Previous studies have applied various methods to evaluate the relationship between low birth weight and exposure to air pollutants, including linear regression (Aguilera et al., 2009), logistic regression (Wilhelm and Ritz, 2005), odds ratio (Maisonet et al., 2001) Poisson regression (Slama et al., 2007), etc. In these studies, using odds ratio or linear, logistic and Poisson regressions implies that every sample is considered independently. In our study, instead, we follow Fotheringham et al (2002), who considered the previously ignored spatial autocorrelation and nonstationarity with Geographically Weighted Regression (GWR). Their approach uses different parameters in the linear regression model to characterize the non-stationarity of relationship between variables. While GWR only works for numerical variables, we explored the association between two binary variables, and the association between numerical values and binary variables. We propose to employ geographically weighted odds ratio and geographically weighted logistic regression with our data to further examine the relationships and provide a better result.

Third, this study can serve as a fundamental guidance for policy makers about future planning and investment. Places where strong correlations between LBW and the exposure to air pollution exist should receive more attention. In addition, the methods and results of the study can inform the National Children's Study, which is a 20 year nation-wide project that Clark is currently participating. The methods used in this program can also be applied in other similar projects, whereas results can be included as part of the ongoing project to make people understand the situation of children's health better.

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