# AIR POLLUTION ASSESSMENT USING LAND-USE REGRESSION MODEL

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## ABSTRACT

Air pollution exposure assessment is the most important step in epidemiological studies for determining the relationship between air pollution and human health effects. One of new collaborative research project in Europe is the Human Early-Life Exposome (HELIX) and the most important part of this project is air pollution exposure assessment. In order to maximize the accuracy of exposure assessment the validated and accurate methods of this process need to be used.

The land-use regression (LUR) model is widely applied to personal air pollution exposure studies. LUR model is based on multiple regression equations, which are used to describe the relationship between measured pollutant concentrations and potential predictor variables computed, using geographic information system (GIS).

The aim of this study was to assess the air pollution of nitrogen dioxide ($NO_2$), nitrogen oxides ($NO_x$), and particulate matter ($PM_{2.5}$, $PM_{10}$) in Kaunas city using LUR model. The measurements of nitrogen oxides were carried out in 40 sites and particulate matter – in 20 sites in study area from the ESCAPE project. GIS predictors were used to develop LUR models for each air pollutant separately. Raster maps of the study area were created to assess the exposure of air pollution.

LUR modelling results showed that annual average variation of nitrogen dioxide and nitrogen oxides concentrations ranged from 8.8 to 66.4 μg/m$^3$ and from 10.9 to 102.0 μg/m$^3$. The average annual concentration of particulate matter ($PM_{2.5}$, $PM_{10}$) varied from 15.6 to 36.2 μg/m$^3$ and from 23.5 to 45,0 μg/m$^3$ in Kaunas city. The average annual values of $NO_2$ and $NO_x$ were 15.4 and 25.2 μg/m$^3$and the concentrations of particulate matter ($PM_{2.5}$, $PM_{10}$) were 18.7 and 26.9 μg/m$^3$.

**Keywords**: air pollution, exposure assessment, GIS, land-use regression model

## 1. Introduction

Several epidemiological studies provide evidence for an association between long-term exposure to air pollution and health effects. Nitrogen dioxide ($NO_2$) is the main traffic-related air pollutant associated with health effects (Bellander *et al.,* 2001; Latza *et al.,* 2009). Research studies found the evidence about the health effects of air pollution from particulate matter (Anderson *et al.,* 2012; Pope *et al.,* 2009). Recent epidemiological studies and collaborative research projects, conducted in various countries, have reported different level relationships between elevate levels of air pollutants and adverse health outcomes (Kampa *et al.,* 2008; Pedersen *et al.,* 2013). The most important part of determining the associations between human health effects and air pollution is air pollution exposure assessment. In order to estimate exposure to air pollutants in large population studies, the dispersion and regression models are commonly used (Jerrett *et al.,* 2005; Nethery *et al.,* 2008). These models are used to assess the concentration of pollutants to each participant based on his residence address, because it would be difficult using real measurements (Hoek *et al.,* 2008).

The land-use regression (LUR) model is widely applied and based on multiple regression equations, which are used to describe the relationship between measured pollutant concentrations and potential predictor variables computed, using geographic information system (GIS) (Johnson *et al.,* 2010; Ryan *et al.,* 2007). The aim of this study was to assess the air pollution in Kaunas city using LUR model.

## 2. Methods

The study was conducted in Kaunas city, Lithuania. GIS data was collected to assess the potential predictor variables and the measurements of nitrogen dioxide ($NO_2$), nitrogen oxides ($NO_x$), and particulate matter ($PM_{2.5}$, $PM_{10}$) were carried out in order to develop LUR model within the ESCAPE project in Kaunas city (Figure 1). The measurements of nitrogen oxides were carried out in 40 sites and particulate matter – in 20 sites in study area.

Raster maps of air pollutants were created using the centroids of 100-m grids over Kaunas city to determine the concentration of $NO_2$, $NO_X$, $PM_{2.5}$ and $PM_{10}$.

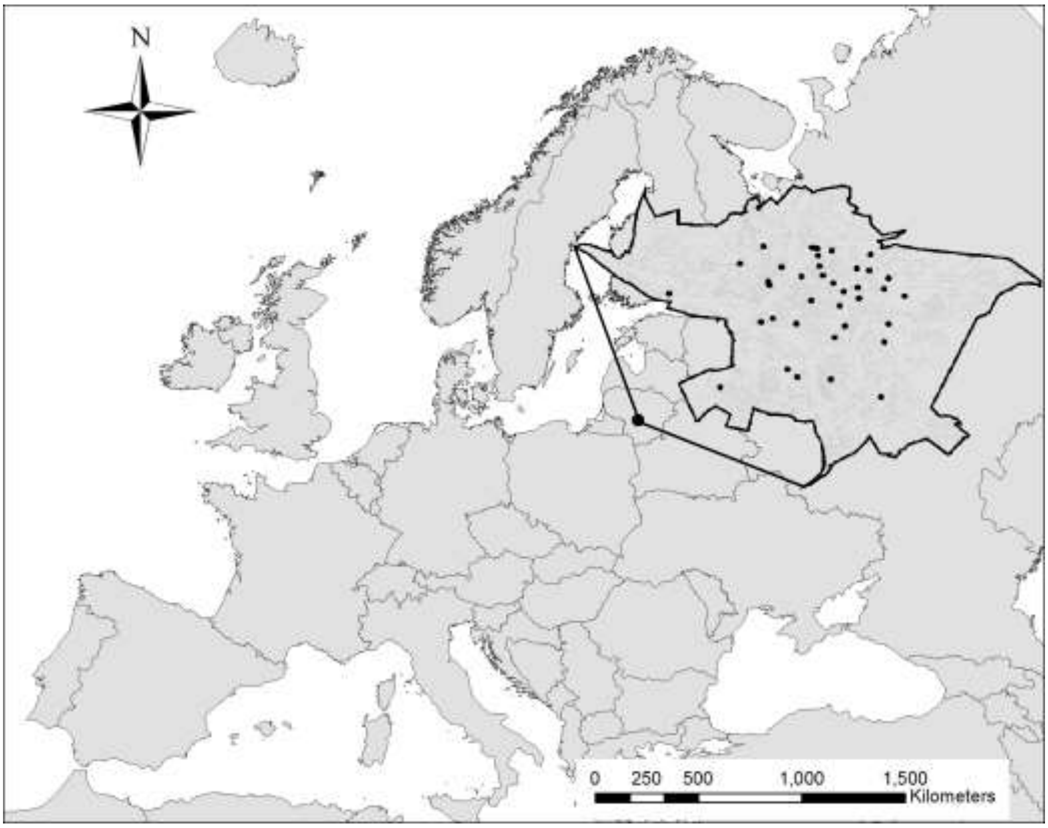


**Figure 1:** Kaunas study area and measurement sites

## 3. Results

GIS predictors were used to develop LUR models for each air pollutant separately. Predictor variables were obtained from GIS database. After regression analysis predictor variables for each modeled pollutant were determined (Table 1). Predictor variables of traffic representation and population density were the most important for developing LUR model.

Using LUR models, annual raster maps for each pollutant were created. Kaunas study area was covered by 100x100 m grids. Each grid had a value of air pollutant concentration. The annual mean concentration of $NO_2$, $NO_X$, $PM_{2.5}$, $PM_{10}$ was calculated using grids of all study area. The annual concentration of $NO_2$ and $NO_X$ ranged from 8.8 to 66.4 µg/m$^3$ and from 10.9 to 102.0 µg/m$^3$. The annual mean concentration of 15.4 and 25.2 µg/m$^3$ was estimated, respectively for $NO_2$ and $NO_X$ in Kaunas city. The annual concentration of $PM_{2.5}$ and $PM_{10}$ varied from 15.6 to 36.2 and from 23.5 to 45.0 µg/m$^3$. The annual mean value of $PM_{2.5}$ and $PM_{10}$ was 18.7 and 26.9 µg/m$^3$.

**Table 1:** Predictors of $NO_2$, $NO_X$, $PM_{2.5}$, $PM_{10}$ LUR models

| Modeled pollutants | LUR model predictors | Number of sites |
|---|---|---|
| $NO_2$ | • Distance to the nearest major road<br>• Heavy-duty traffic intensity on nearest road | 40 |
| $NO_X$ | • Number of inhabitants in 1000 m buffer size<br>• Distance to the nearest major road<br>• Heavy-duty traffic intensity on nearest road | 40 |
| $PM_{2.5}$ | • Number of inhabitants in 100 m buffer size<br>• Traffic intensity on nearest major road | 20 |
| $PM_{10}$ | • Number of inhabitants in 100 m buffer size<br>• Traffic intensity on nearest major road | 20 |

**Table 2:** The annual mean concentration of pollutants (μg/m$^3$) in Kaunas city

| Pollutant | Mean concentration | Min | Max | Standard Deviation |
|---|---|---|---|---|
| $NO_2$ | 15.4 | 8.8 | 66.4 | 5.19 |
| $NO_X$ | 25.2 | 10.9 | 102.0 | 11.39 |
| $PM_{2.5}$ | 18.7 | 15.6 | 36.2 | 2.12 |
| $PM_{10}$ | 26.9 | 23.5 | 45.0 | 2.19 |

## 4. Conclusions

We collected nitrogen dioxide ($NO_2$), nitrogen oxides ($NO_x$), and particulate matter ($PM_{2.5}$, $PM_{10}$) measurement data, potential GIS predictors and developed annual land-use regression (LUR) model for each pollutant in Kaunas city, Lithuania. Spatial distribution and mapping of $NO_2$, $NO_X$, $PM_{2.5}$, $PM_{10}$ was produces by LUR models, which is useful for accurate prediction of pollutants concentration and assessment of exposure in health studies.

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