Respiratory-related Disease in Vilnius City Districts and Relationships to CO, NO_2, SO_2 Levels and the Air Pollution Index (API)

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Introduction & Background:

In a time of intensive city development throughout Lithuania and in many other countries of central and eastern Europe, protecting air quality for city residents is of vital importance to protecting public health. Although pollution from stationary sources has declined in the past few years, an increase in pollution from mobile sources yielded an air pollution total of 107,900 tons in Vilnius in 1996 (Zickus, 1999). Carbon monoxide (CO) accounted for about 77% of this total by weight, while nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and other pollutants comprised the remainder. Currently mobile sources, mostly automobiles, account for 88% of air pollution in Vilnius.

Table 1. Diseases examined for this study.

Code	INTERNATIONAL CLASSIFICATION OF DISEASES, 9th Revision
162	Malignant neoplasm of trachea, bronchus, and lung
410	Acute myocardial infarction
460	Acute nasopharyngitis [common cold]
461	Acute sinusitis
462	Acute pharyngitis
464	Acute laryngitis and tracheitis
465	Acute upper respiratory infections of multiple or unspecified sites
466	Acute bronchitis and bronchiolitis
472	Chronic pharyngitis and nasopharyngitis
473	Chronic sinusitis
476	Chronic laryngitis and laryngotracheitis
477	Allergic rhinitis
480	Viral pneumonia
481	Pneumococcal pneumonia
482	Other bacterial pneumonia
485	Bronchopneumonia, organism unspecified
486	Pneumonia, organism unspecified
487	Influenza
490	Bronchitis, not specified as acute or chronic
491	Chronic bronchitis
493	Asthma

In addition to an aesthetic influence on air quality in the commonly known forms of smog and smell, these air quality indicators are an indicator of a real influence on public health. Epidemiological studies prove that increased levels in CO, NO_2, and SO_2, increase the instances of several types of respiratory infections, heart disease, and other respiratory-related diseases (Pershagen G, 1995; Wojtyniak B, 1997). Given this conditions there is a need to set air quality standards, monitor air quality, and meet air quality standards in order to protect public health. Further people should be educated about the influence of air quality on public health and how they can help reduce their exposure to unhealthy conditions and reduce their contribution to air pollution.

This study examines the relationship between air quality and public health in Vilnius by comparing air quality to various diseases in Vilnius city districts. CO, NO_2, SO_2, and the Air Pollution Index (API) are compared in relation to a group of respiratory-related diseases and other diseases that are known to be influenced by air quality. Results of the analysis show a positive relationship between air quality indicators and several diseases. This study will hopefully highlight the need to meet standards, seek ways to improve quality, and develop other ways of minimizing the health risk from air pollution.

Data & Methods of Analysis:

Public Health Data

Public health data were obtained from the public health database maintained by the Vilnius Public Health Center or *Vilniaus Visuomenes Sveikatos Centras* (VSC). Each time a patient visits a polyclinic in Vilnius, a record is sent to the Vilniaus VSC recording the diagnosis, the patient's age, residence, the date, and other useful information. The data spanned the years 1991 to 1995 for ages 0-19 and years 1991 and 1992 for all ages. After 1992, only records for those under age 20 were kept. The data set contains over 1 million records and diseases are recorded utilizing the *International Classification of Diseases, 9th Revision* (ICD) codes (Министерство здравоохранения СССР).

Raw data from the Vilniaus VSC was collected in a DB4 database format. In order to analyze the information, a Microsoft Access database was designed and the information imported. Also developed in the database was a feature to analyze the data geographically by city district. To accomplish this, each street in the public health database was assigned to the city district in which it is located. This allowed for the creation of queries based on the city districts; i.e. one could then calculate the number of diagnoses of a particular illness by city district.

Utilizing a data table that also included the population living on each street in Vilnius, annual disease rates were calculated per 100,000 residents. In total, two public health data sets were composed; one contained all ages for years 1991 to 1992 and the second contained ages 0-19 but spanned from 1991 to 1995. (This is again because health data after 1992 was only collected for children). Since to analyze the data for years 1991 to 1995 we only are looking at patients aged 0-19, we had to multiply by the portion of the population represented by the age-group 0-19. This was roughly calculated as 0.261 (Vilnius Statistical Office). The diseases evaluated for this study are shown in **Table 1**.

Air Quality Data

In 1995 a new project by the name of "Air Quality Management in Vilnius City" was initiated by the Environmental Protection Ministry of Lithuania and the Swedish government. This project saw the implementation of a computerized air pollution management system know as "Airviro." This system consists of three automatic pollutant monitoring stations in Vilnius which monitor concentrations of CO, NO_2, NO, NO_X, SO_2, and O_3. These three stations are located in Senamiestis, Žirmūnai, and Žverynas. Measurement data is sent hourly to a central database and is available via the Internet (http://vilnair.gamta.lt/).

The Air Quality Management Group at the Environmental Protection Ministry constructed models based on these measurements, taking into account meteorological conditions in order to simulate pollutant cover throughout Vilnius's city districts. CO, NO_2, and SO_2, concentrations are plotted on a map of Vilnius, allowing for the pollutant level in each district to be estimated. Also, an API is calculated in Vilnius taking into account government standards for CO, NO_2, and SO_2. This is the formula for calculating the API:

$$\mathbf{API = C_{(CO)}/LV_{(CO)} + C_{(NO2)}/LV_{(NO2)} + C_{(SO2)}/LV_{(SO2)}}$$

Where,
$C_{(CO)}$ = CO concentration
$LV_{(CO)}$ = Hourly Limit Value for CO
$C_{(NO2)}$ = NO_2 concentration
$LV_{(NO2)}$ = Hourly Limit Value for NO_2
$C_{(SO2)}$ = SO_2 concentration
$LV_{(SO2)}$ = Hourly Limit Value for SO_2

Based on the API, each Vilnius city district was classified as unpolluted, semi-polluted, and very

Table 2. Maximum Permissible Concentrations (HN 33-1998) μg/m3

	CO*	SO_2	O_3	NO_2	NO
Hourly Average (DLK)	5	500	160	85	400
24 Hour Average (DLK)	3	50	30	40	60

CO* - concentration, mg/m3.
Note: O_3 and NO where not evaluated in this study and are only presented for reference.

polluted, and then set to numbers 1,2, and 3

respectively. In this way "1" denotes clean air and "3" denotes very polluted air. **Table 2** shows Lithuania Hygienic Norm 33-1998 standards for selected air pollutants.

Analysis

Based on the results for air quality indicators and public health diagnosis rates calculated in each of the 20 city districts, regression analysis was performed to look for relationships utilizing Systat 7.0. Air pollution indicators were held as the independent and the disease rates were held as the dependent. The results of these linear regression analyses are presented in **Table 6**. The regression analysis is a unique tool because it tells us how much of the variability in our dependent variable is explained by our independent variable. This is enumerated in the R-squared (R^2) value in **Table 6**. The R^2 value is equal to 1.0 minus the ratio of the residual variability of the Y variable to the original variance (StatSoft, Inc.). If X and Y are perfectly related the residual variance will be equal to 0.0 and thus the R^2 value equal to 1.0. For example, if we have an R^2 value of 0.55, then we know that the relationship explains 55% of the variability in the data, and we have 45% residual variability. In short, the closer the R^2 value is to 1.0, the more of the variability we have explained. The closer R^2 value is to 0.0, the less we have explained.

Table 3. Average annual number of diagnoses per 100,000 for years 1991-1992 for the age group 0-100.

Disease	Acute myocardial infarction	Acute nasopharyngitis [common cold]	Acute laryngitis and tracheitis	Chronic pharyngitis and nasopharyngitis	Chronic sinusitis	Chronic laryngitis and laryngotracheitis	Viral pneumonia	"Bronchitis, not specified as acute or chronic"	Chronic bronchitis
ICD-9 CODE	410	460	464	472	473	476	480	490	491
Total Number of Diagnoses	343.00	28160.00	10536.00	826.00	238.00	475.00	351.00	603.00	948.00
ANTAKALNIO	46.72	2978.02	1233.78	58.83	48.45	6.92	1.73	112.48	41.53
FABIJONISKIU	4.36	1664.41	740.10	13.08	1.09	4.36	4.36	105.73	28.34
JUSTINISKIU	10.39	1307.56	1512.98	39.24	1.15	8.08	8.08	65.78	78.48
KAROLINISKIU	17.52	1202.76	474.87	60.33	13.62	5.84	17.52	15.57	54.49
LAZDYNU	29.78	1463.71	604.20	51.06	12.76	17.02	17.02	34.04	110.63
N.VILNIOS	1.74	1115.76	299.86	6.97	0.00	1.74	5.23	3.49	0.00
NAUJAMIESCIO	53.73	2282.65	383.04	65.86	10.40	135.19	74.53	6.93	116.13
NAUJININKU	22.96	1406.16	408.07	28.26	3.53	14.13	70.66	70.66	88.33
PASILAICIU	11.62	2791.54	1839.09	38.72	0.00	1.94	11.62	94.86	94.86
RASU	51.81	1861.57	524.97	58.71	20.72	44.90	27.63	151.97	69.08
SENAMIESCIO	42.55	2689.16	483.20	60.40	24.71	65.89	72.75	35.69	116.68
SESKINES	0.00	1679.28	666.87	5.18	3.46	1.73	10.37	39.74	38.01
SNIPISKIU	34.33	2474.88	861.37	87.39	35.89	18.73	20.29	17.16	102.99
VERKIU	22.55	2668.03	608.96	82.26	27.86	9.29	27.86	14.59	61.03
VILKPEDES	40.72	3833.48	465.37	71.74	21.33	238.50	141.55	7.76	139.61
VIRSULISKIU	42.07	1324.17	1406.31	52.09	8.01	12.02	16.03	6.01	50.08
ZIRMUNU	56.98	3040.56	1049.78	76.83	64.75	18.13	11.22	80.29	84.60
ZVERYNO	28.53	1785.28	570.64	118.20	36.68	20.38	12.23	4.08	142.66

Source: The raw data for these geographical calculations were obtained from the Vilniaus Visuomenes Sveikatos Centras database.

Also included is the p-value of the relationship. The p-value is a measure of the significance of the relationship in the sense that the samples under examination are representative of the total population. The p-value is essentially based on the sample size, a larger sample size being more representative of the whole population. A p-value of 0.093 means that there is a 9.3% chance that the relationship between the variables is a complete "fluke." For the purpose of this study a p-value < 0.05 has been chosen for values that we will accept, which corresponds to "confidence level" of α **> 95%**. Although the R^2 value and the p-value are related, one often refers to the R^2 value as a measure of strength or magnitude and the p-value as a measure of significance.

Sources of Error

In this study, socioeconomic and other factors may also influence public health in addition to environmental conditions and be confounders in the analysis (Anderson R, 1997). Age distribution throughout city districts may not be uniform and results may be affected if a given disease afflicts a certain age group to a greater extent than other age groups.

Results:

Public Health Data Tables

There are two tables presenting public health data. In these tables, each city district in Vilnius is listed along with a group of diseases that were examined. **Table 3** shows the average annual number of diagnoses per 100,000 people averaged over years 1991 and 1992 and including all ages, 0-100 years. **Table 4** shows the average annual number of diagnoses per 100,000 people as well. However, this table is averaged over years 1991 to 1995 and includes only persons aged 0-19 years. After 1992, polyclinics only collected this data for patients aged 0-19 years. The total number of diagnoses are also listed in the tables.

The vast majority of diseases chosen for examination were respiratory-related infections of various locations. Also chosen was Acute Myocardial infarction (410) due to a known relationship in previous epidemiological studies to CO levels. For the sake of brevity, only data for diseases which showed a relationship to air pollutants are presented in the tables.

Table 4. Average annual number of diagnoses per 100,000 for years 1991-1995 for the age group 0-19.

Disease	Acute nasopharyngitis [common cold]	Acute laryngitis and tracheitis	Chronic pharyngitis and nasopharyngitis	Chronic sinusitis	Chronic laryngitis and laryngotracheitis	Viral pneumonia	"Bronchitis, not specified as acute or chronic"	Chronic bronchitis
ICD-9 CODE	460	464	472	473	476	480	490	491
Total Number of Diagnoses	59973.00	13716.00	214.00	185.00	35.00	301.00	715.00	942.00
ANTAKALNIO	11858.92	3701.94	15.91	58.34	5.30	5.30	291.70	10.61
FABIJONISKIU	6910.55	2694.40	6.68	3.34	3.34	10.02	141.99	71.83
JUSTINISKIU	4911.57	2483.20	12.38	0.00	0.00	14.15	91.97	109.66
KAROLINISKIU	5422.82	1279.64	11.93	5.97	0.00	98.43	26.85	47.73
LAZDYNU	6201.50	1428.11	13.04	6.52	0.00	254.32	39.13	123.90
N.VILNIOS	1734.13	459.59	5.34	0.00	2.67	8.02	5.34	0.00
NAUJAMIESCIO	8585.47	680.04	21.25	13.28	15.94	10.63	0.00	154.07
NAUJININKU	5501.56	1042.37	21.66	5.41	0.00	8.12	113.71	316.77
PASILAICIU	7752.56	3091.53	20.77	0.00	5.93	32.64	121.64	195.82
RASU	5780.84	1069.35	5.29	84.70	10.59	5.29	280.57	100.58
SENAMIESCIO	8526.35	877.25	10.52	33.66	0.00	27.35	71.53	159.88
SESKINES	6102.73	1713.00	2.65	2.65	2.65	21.18	58.25	103.26
SNIPISKIU	8274.54	2104.51	4.78	33.48	11.96	16.74	78.92	133.92
VERKIU	7903.62	1006.51	4.07	46.77	2.03	20.33	18.30	79.30
VILKPEDES	11111.44	1102.53	20.80	50.52	8.92	5.94	0.00	356.61
VIRSULISKIU	5818.24	755.30	9.21	0.00	3.07	171.94	30.70	61.41
ZIRMUNU	10418.10	2255.89	14.55	51.60	0.00	6.62	224.93	54.25
ZVERYNO	6114.93	1617.74	12.49	74.95	0.00	68.71	0.00	274.83

Source: The raw data for these geographical calculations were obtained from the Vilniaus Visuomenes Sveikatos Centras database.

The tables can be referred to for the identification of city districts having the highest and lowest disease rates. As a highlight of the findings, Naujamiestis, Rasos, and Zirmunai, have the highest rates of Acute Myocardial infarction (410). Chronic bronchitis (491) is most prevalent in the city districts of Zverynas, Vilkpedes, Senamiestis, and Naujamiestis for the 0-100 year age group.

Air Quality Data Table

Table 5. Estimated concentractions of selected air pollution indicators for 1996.

City District	API	CO (mg/m^3)	NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)
ANTAKALNIO	1	2.5	40	12
FABIJONISKIU	1	1.5	35	12
JUSTINISKIU	1	2	40	10
KAROLINISKIU	1	1.5	37	13.5
LAZDYNU	1	1.5	35	15
N.VILNIOS	1	1	35	10
NAUJAMIESCIO	2.5	4.5	60	17
NAUJININKU	1.5	2.5	45	15
PASILAICIU	1	1.5	35	10
RASU	1	1.5	40	13
SENAMIESCIO	2.5	3.5	50	15
SESKINES	2	3.5	50	15
SNIPISKIU	2.5	4	55	17
VERKIU	1	1.5	35	12
VILKPEDES	2.5	4	55	15
VIRSULISKIU	1.5	3	45	11
ZIRMUNU	2	3	45	15
ZVERYNO	2.5	3.5	50	20

Source: Data was extrapolated from maps of Vilnius produced by the Air Quality Management Group at the Ministry of Environmental Protection in 1996.

Table 5 shows the estimated concentrations of selected air pollution indicators for 1996. Perhaps it would have been more conducive to use data from 1995 or slightly earlier, but the data were not available given the 1996 start date of the air quality monitoring program. However, the air quality conditions in Vilnius have not drastically changed over the time period of the study and it is believed that air quality data among districts should still be quite representative.

Based on the API, the worst air conditions are found in the city districts of Zverynas, Vilkpedes, Snipiskes, Senamiestis, and Naujamiestis. The best air conditions are found in Antakalnis, Fabijoniskes, Justiniskes, Karoliniskes, Lazdynai, N. Vilnia, Pasilaiciai, Rasos, and Verkiai.

Analysis Table of Results

Table 6 shows the results of regression analyses comparing air quality indicators to these disease rates. Where there appear numbers in a particular comparison, the p-value of the regression was less than 0.05 and the α or confidence level was greater than 95%. This essentially means that there is only a 5% chance that the relationship we found was a statistical "fluke." These relationships were accepted as being statistically significant. Presented adjacent to the p-value is the R-squared value, the measure of strength. Again, the R-squared value tells us how much of the variation in a disease rate can be explained by the air pollution indicator.

Where there appear only an "X" in the table the p-value of the relationship was greater than 0.05 but less than 0.10. Although these relationships were not considered significant in this study, there does seem to be some grounds for a relationship that might be clarified with further study. Where there is simply a blank spot in the chart, p-values were greater than 0.10 and there seems to be no significant statistical relationship.

Discussion:

This results of the study showed several interesting relationships, none perhaps stronger than the relationship of air pollution indicators to several chronic respiratory infections. In particular, Chronic pharyngitis and nasopharyngitis (472), Chronic laryngitis and laryngotracheitis (476), Bronchitis, not specified as acute or chronic (490), Chronic bronchitis (491) showed very low p-values and high R-squared values. These findings were true for both age groups, and across all air pollution indicators.

Although this finding is documented in other cities, this study helps highlight the problem in Vilnius. CO, NO_2, and SO_2 lead to an increase in disease, especially when they are present in concentrations above Hygienic Norm standards. To illustrate the extent of the influence, an average rate of chronic bronchitis (491) was calculated for city districts with an API of "unpolluted" and for those with an API of "very polluted." The average rate for the unpolluted districts was 125 per 100,000 for the 0-19 year age group, and in the polluted districts the rate was 216. That means that residents of the very polluted city districts have a 72% greater chance of coming down with chronic bronchitis than residents of the unpolluted districts. A similar percentage increase was also found for the 0-100 year age group.

Table 6. Statistical results of regression analysis between air quality indicators and selected diseases in Vilnius city districts.

		INTERNATIONAL CLASSIFICATION OF DISEASES	Acute myocardial infarction	Acute nasopharyngitis [common cold]	Acute laryngitis and tracheitis	Chronic pharyngitis and nasopharyngitis	Chronic sinusitis	Chronic laryngitis and laryngotracheitis	Viral pneumonia	Bronchitis, not specified as acute or chronic	Chronic bronchitis
Air Quality Indicator	**Age Group**	**ICD-9 CODE**	**410**	**460**	**464**	**472**	**473**	**476**	**480**	**490**	**491**
	0-19 Years	p-value									0.03
		R^2									0.27
	0-100 Years	p-value	x	x		0.05		0.01	0.02	0.05	0.00
API		R^2	x	x		0.23		0.32	0.30	0.22	0.43
	0-19 Years	p-value		0.03				x			x
		R^2		0.25				x			x
	0-100 Years	p-value	0.04	x		x		0.01	0.03		0.01
CO		R^2	0.23	x		x		0.32	0.27		0.34
	0-19 Years	p-value						0.03			0.04
		R^2						0.25			0.24
	0-100 Years	p-value	0.05					0.01	0.01		0.01
NO_2		R^2	0.22					0.39	0.34		0.34
	0-19 Years	p-value									0.03
		R^2									0.26
	0-100 Years	p-value			0.03	0.01	x				0.00
SO_2		R^2			0.25	0.35	x				0.46

Notes: Where the p-values where less than 0.05 we accepted the relationship. This is a statistical standard equal to the conficence level (alpha) = 95%.
x = p-values were between 0.10 and 0.05

Another interesting finding is the apparent relationship between Acute myocardial infarction (410) and levels of CO (R-squared = 0.23) and NO_2 (R-squared = 0.22) in the 0-100 year age group. This finding holds consistent with prior epidemiological studies.

CO, NO_2, and SO_2 act in a variety of ways to weaken the body's ability to function properly. CO is known to lead to these health effects: "aggravation of angina pectoris and other aspects of coronary heart disease, decrease exercise tolerance in persons with peripheral vascular disease and lung disease, impairment of central nervous system functions, and possible increase risk to fetuses (South Coast Air Quality Management District, 1999)." NO_2 is known to lead to these health and other effects: "potential to aggravate chronic respiratory disease and respiratory symptoms in sensitive groups, risk to public health implied by pulmonary and extra-pulmonary biochemical and cellular changes and pulmonary structural changes, and contribution to atmospheric discoloration." SO_2 is known to lead to these health effects: "bronchoconstriction accompanied by symptoms which may include wheezing, shortness of breath and chest tightness, during exercise or physical activity in persons with asthma."

Although this is a preliminary study, the relationships found show that a strong influence is being exhibited by air quality on public health. These findings merit further examination and bring attention to the need for cities such as Vilnius to take strong steps to bring air quality into compliance with government norms. It is further hoped that other cities in Lithuania will begin to take the same steps toward more effective monitoring and management of air quality.

Conclusions:

- Higher CO, NO_2, and SO_2 levels have been proven in past studies to lead to higher rates of respiratory and other illnesses.
- Air pollutant levels are not evenly distributed throughout Vilnius, thereby exposing residents of certain districts to air of poor quality.
- Disease rates for respiratory-related, and other diseases are not evenly distributed throughout city districts in Vilnius.
- Districts with more polluted air closely correspond to those with higher respiratory-related disease rates.
- Residents in city districts with an API of "very polluted" had on average a 72% higher rate of Chronic bronchitis (491) than residents of districts with an "unpolluted" API. Similar increases were noted with other respiratory-related diseases in this study.

Recommendations:

- There needs to be a plan for coming into compliance with air pollutant standards.
- Monitoring should be continued in Vilnius and expanded to other cities in Lithuania with potential air pollution problems.
- Residents should be supplied with information about air quality conditions, how to minimize their health risk from poor air quality, and how to reduce their contribution to air pollutant levels.

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