



Observable Effects of Atmospheric Pollution on Outpatient and Inpatient Morbidity in Bulgaria

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Abstract

Background: One of Europe's most well-developed industrial regions is found in the Republic of Bulgaria. The industrialization of the region has a big impact on air pollution. Thermal power plant "Maritza East" (the largest of its kind in southeastern Europe), the army training range, machine manufacturers, household heating and high volume of automobile traffic are all major sources of pollution in the region.

Methods: A five year study (2009-2013) followed yearly concentrations of principal atmospheric pollutants such as sulfur dioxide, dust, nitrogen dioxide, lead aerosols and hydrogen sulfide, and the way in which those levels had an effect on morbidity (outpatient and inpatient medical care) in the area. Statistical processing of data has been completed to represent and analyze the collected data in nonparametric and alternative format.

Results: Atmospheric pollution affects human health directly through pathological changes in the human organism. The registered outpatient care provided for the period 2009-2013 is highest for diseases of the cardiovascular system (11.85%), the respiratory system (17.34%) and the genitourinary system (9.76%). The registered rate of hospitalization for the same period is for diseases of the digestive system (11.90%), the cardiovascular system (11.85%), respiratory system (10.86%) and the genitourinary system (8.88%).

Conclusion: The observed period shows a decrease in average yearly concentrations of the principal atmospheric pollutants in the industrial region (Bulgaria) and reflects a decrease in morbidity based on outpatient care and an increase in morbidity by inpatient care (hospitalization). Our findings should be corroborated in future longitudinal studies.

Keywords: Atmospheric pollution, Morbidity, Industrial region, Bulgaria

Introduction

Pollution of the atmosphere contributes to global pollution. The beginning of the twenty first century saw a rise in urbanization and industrialization which exacerbated such problems and their disturbance of the ecological infrastructure of the world.

Atmospheric pollution affects human health directly through pathological changes in the human organism and indirectly through the erosion of ecological systems, destruction of cultural and architectural monuments and memorials, and others. All of this is related to economic losses as well (1).

Marie-Eve Heroux of the World Health Organization's Regional Office for Europe stated that "Air pollution affects everyone in developed and developing countries alike". Globally, total pollution of nature is responsible for causing a quarter of all diseases (2). Most vulnerable to these effects are children, asthmatics, older people and the sick. The health risk is higher for people living in the highly industrialized regions of Europe. Therefore, the goal of the European Union in protecting the environment is to decrease atmospheric pollution. This is accomplished by restricting emissions, and

setting limits and target values for determining air quality. Policy package for clean air in Europe was adopted in Dec 2013 which includes Clean Air Programme for Europe with measures to ensure that existing targets are met by 2020, and calls for the European Union to cut air pollution by 2030. One of Europe's most well-developed industrial regions is found in the Republic of Bulgaria. It is a country located in southeastern Europe, in the eastern part of the Balkan Peninsula. The industrialization of the region has a big impact on air pollution, especially in recent years (3-5). The region has an area of 1019.1 square meters and total population of 156,662 people. Totally 137,834 of them live in the area's largest city- Stara Zagora; the remaining 18, 828 people live in the 52 surrounding villages.

The most significant source of atmospheric pollution in the area is a complex of coal power plants "Maritza East" (the largest of its kind in southeastern Europe). It consists of surface coal mines and three thermal power plants, as well as an army training range. The "Maritza East" complex is located 40 km southeast of the city of Stara Zagora and has an area of 240 square meters. The army range is located 7 km northwest of Stara Zagora, 420 meters above sea level and occupies an area of 95.6 square meters.

Other sources of atmospheric pollution in the area are businesses which distribute auto gas, natural gas, benzene and diesel fuel, as well as machine manufacturers, textile and food industries, household heating, and high traffic volume (two major trans-European highways cross the region). These factors combine with unfavorable meteorological conditions to substantially pollute the air in the region.

Therefore, pollution from principal atmospheric pollutants such as sulfur dioxide (SO₂), dust, nitrogen dioxide (NO₂), lead aerosols and hydrogen sulfide (H₂S), plays a major role in disturbing the ecology of this industrial region. Such pollution also harms human health. Organic hydrocarbons (benzene) and carbon monoxide are also important atmospheric pollutants. These pollutants do not show correlations with various diseases do not harm to human health, because of little or no

readings and therefore are not subject to examination, and not evaluated in this study.

A very precise indicator of human health deviation is population morbidity. Morbidity is generally divided in two categories-outpatient care and inpatient care (hospitalization). As a whole, morbidity is affected by changes in atmospheric pollutant concentrations (6, 7). The Republic of Bulgaria monitors air quality throughout the year. This is done by government agencies, namely the Regional Inspectorate of Environment and Water, by observing a standard set of atmospheric pollutants and comparing their values to those set by the Clean Air Act, Last amendment (Bulgarian State Gazette) (8).

The goal of this work was to examine how atmospheric pollutants affect the onset and development of disease. Such effects are examined for the time period 2009-2013 and accounted for by disease classification, as per International Classification of Diseases-10. A relationship between atmospheric pollutants and onset and development of disease is determined by studying rates of outpatient and inpatient care in the aforementioned industrial European region.

Materials and Methods

Collected data for the time period 2009-2013 included yearly concentration values for the following pollutants: sulfur dioxide, dust particles, nitrogen dioxide, lead aerosols and hydrogen sulfide. Data were collected at four stations that monitor air quality in the region. These stations are: Automatic measuring station (AMS) - Zelen Klin; Differential optical absorption spectroscopy (DOAS) "Ostra Mogila" - Ostra Mogila village; Differential optical absorption spectroscopy(DOAS) "Mogila EKO 1" - Ostra Mogila village; Manual measuring station "Regional inspectorate of environment and water"(RIEW) -Stara Zagora. Automatic measuring station (AMS) and Differential optical absorption spectroscopy (DOAS) register continuously the concentrations of basic pollutants in the air, (24 h), then the average collected information hourly is fed in real time to the relevant regional dispatching stations (regional databases in

Regional inspectorate of environment and water - RIEW, Stara Zagora -Control system for air quality) and in central dispatch point of Executive Environment Agency, Sofia- national databases for monitoring air quality.

Samples have been collected four times a day in hand point. In general the weekends are not working days. This method has been suitable for continuous monitoring of the average urban air pollution. The results have been compared to the norms, set forth by the legislation of Republic of Bulgaria (9).

Information about registered outpatient and inpatient care has been obtained from the Regional Health Inspectorate (RHI) in the area. The information is about nineteen disease classifications as described in the International Classification of Diseases-10. The results have been divided into three age groups: 0-17 yr old, 18 and older, and population as a whole.

Statistical processing of data has been completed to present and analyze the collected data in non-parametric and alternative analysis.

Results

The main sources of atmospheric pollution in the studied region are organized industrial emissions, high traffic volume, as well as private and public heating.

The highest yearly average value of sulfur dioxide ($12.96 \mu\text{g}/\text{m}^3$) for the time period 2009-2013 has been recorded at AMS - Zelen Klin in 2011. The lowest recorded yearly average ($4.71 \mu\text{g}/\text{m}^3$) was recorded the same year, but at DOAS - Ostra Mogila. Despite the fluctuations in the yearly average concentrations of sulfur dioxide, all measured values for the observed period are tenfold smaller than the norms set forth by Ordinance №12/15.07.2010. Average yearly concentration values of PM_{10} recorded in AMS - Zelen Klin and DOAS-Ostra Mogila are under the threshold value of $40 \mu\text{g}/\text{m}^3$. All measured values for dust particles PM_{10} at RIEW-Stara Zagora for 2009, 2010, and 2011 are above threshold value. A pattern of decreasing average yearly concentration values of nitrogen dioxide is observed from 2009 to 2013.

The highest average value ($30.62 \mu\text{g}/\text{m}^3$) is recorded in 2009 at AMS - Zelen Klin. The lowest average value ($3.53 \mu\text{g}/\text{m}^3$) is recorded at DOAS - Ostra Mogila in 2013. Despite a pattern of increasing average yearly values of lead aerosols toward the end of the observed period, recorded concentrations do not exceed norms set forth by Bulgarian legislature- $0.5 \mu\text{g}/\text{m}^3$. Recorded average yearly concentration values of hydrogen sulfide are within the range considered safe for human health.

To understand the complex relationship between air pollutants and morbidity in the industrial region, inpatient and outpatient medical care rates were considered for the period 2009-2013. Nineteen disease classifications, as per ICD-10, were used and the results are divided into three age groups: 0-17 yr old, 18 and older, and the population as a whole.

Table 1 shows morbidity based on outpatient medical care provided. The population in the region is divided into age groups. Of the nineteen disease classifications considered, those aged 0 to 17 most often suffer from conditions of the respiratory system (47.20%). Following are some infectious and parasitic diseases (10.92%), diseases of the eye and adnexa (5.74%), and diseases of the genitourinary system (5.29%). For those aged 18 and above, circulation system disorders (22.77%) are most common. Following are respiratory system disorders (10.87%), and disorders of the genitourinary system (10.27%). In the ranking of diseases for the population as a whole, most common are those of the circulatory system (22.99%). They are followed by respiratory system disorders (17.34%). The third most common afflictions in this group are diseases of the genitourinary system (9.76%).

When analyzing morbidity from hospitalization rates, diseases of the respiratory system are most prevalent for the 0-17 yr old age group (36.93%). Second are some infectious and parasitic diseases (16.38%). Untimely and incorrect treatments can also affect the digestive system. This is most common in younger children. The third most common affliction of the group 0-17 yr old is diseases of the digestive system (11.36%). The most preva-

lent diseases afflicting the 18 yr and older group, per hospitalization rates, are those of the circulatory system (14.26%). They are followed by classification XV- Pregnancy, childbirth and puerperium and diseases of the digestive system- 12.02% and 12.01%, respectively. Diseases of the genitourinary system account for 9.54% of hospitalization cases in people 18 and older. The results show that for the population of the industrial region as a whole, disease of the digestive system and diseases of the circulatory system are equally responsible for hospitalization rates- 11.90 and 11.85 percent, respectively. As for the second (18 yr and older) and third (population as a whole) groups it

is worth noting the affliction of the eye and adnexa- 9.29% and 7.72%, respectively (Table 2). Morbidity as structured by inpatient medical care (hospitalization) rates presented in three age groups is shown in Table 2. Bearing in mind the results from this analysis of morbidity, the biggest interest for us are those groups of diseases, presenting the biggest relative percentage, such as diseases of the organs of circulatory system and the diseases of the respiratory system. In consideration of subcategories of classification-IX: Diseases of the Circulatory System, based on outpatient medical care provided, of note is the exceptionally high rate of hypertensive disease (60.70%).

Table 1: Morbidity in an industrial region based on outpatient care rate of the population and represented into three age groups

Classification Number	Classification name per ICD-10	0-17 yr old %	18 yr and older %	Population as a whole %
I	Certain Infectious and parasitic diseases	10.92	2.60	4.09
II	Neoplasms	0.50	2.22	1.91
III	Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	0.97	0.84	0.86
IV	Endocrine, nutritional and metabolic diseases	1.17	7.43	6.31
V	Mental and behavioral disorders	0.89	2.40	2.13
VI	Diseases of the nervous system	1.47	4.66	4.09
VII	Diseases of the eye and adnexa	5.74	6.66	6.50
VIII	Diseases of the ear and mastoid process	2.24	1.99	2.03
IX	Diseases of the circulatory system	0.97	27.77	22.99
X	Diseases of the respiratory system	47.20	10.87	17.34
XI	Diseases of the digestive system	5.01	4.84	4.87
XII	Diseases of the skin and subcutaneous tissue	4.72	2.67	3.04
XIII	Diseases of the musculoskeletal system and connective tissue	1.76	9.30	7.96
XIV	Diseases of the genitourinary system	5.29	10.72	9.76
XV	Pregnancy, childbirth and puerperium	0.54	0.33	0.37
XVI	Certain conditions originating in the perinatal period	0.20	0.00	0.04
XVII	Congenital malformations, deformations and chromosomal abnormalities	2.09	0.13	0.48
XVIII	Symptoms, signs, and abnormal clinical and laboratory findings not elsewhere classified	4.25	1.24	1.77
XIX	Injury, poisoning, and certain other consequences of external causes	4.06	3.33	3.46

Table 2: Morbidity in an industrial region based on inpatient medical care (hospitalization) rates and represented in three age groups

Classification Number	Classification name per ICD-10	0-17 yr old %	18 yr and older %	Population as a whole %
I	Certain Infectious and parasitic diseases	16.38	2.70	5.16
II	Neoplasms	0.62	9.37	7.80
III	Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	2.45	1.39	1.58
IV	Endocrine, nutritional and metabolic diseases	0.35	4.99	4.15
V	Mental and behavioural disorders	0.01	0.00	0.00
VI	Diseases of the nervous system	1.40	2.23	2.08
VII	Diseases of the eye and adnexa	0.54	9.29	7.72
VIII	Diseases of the ear and mastoid process	1.93	2.19	2.14
IX	Diseases of the circulatory system	0.86	14.26	11.85
X	Diseases of the respiratory system	36.93	5.17	10.86
XI	Diseases of the digestive system	11.36	12.01	11.90
XII	Diseases of the skin and subcutaneous tissue	1.56	1.53	1.54
XIII	Diseases of the musculoskeletal system and connective tissue	0.94	4.86	4.16
XIV	Diseases of the genitourinary system	5.86	9.54	8.88
XV	Pregnancy, childbirth and puerperium	3.94	12.02	10.57
XVI	Certain conditions originating in the perinatal period	5.15	0.00	0.92
XVII	Congenital malformations, deformations and chromosomal abnormalities	1.32	0.27	0.46
XVIII	Symptoms, signs, and abnormal clinical and laboratory findings not elsewhere classified	0.32	0.35	0.34
XIX	Injury, poisoning, and certain other consequences of external causes	7.71	7.78	7.77

More than half of the population aged 18 and above and the population as a whole have problems with blood pressure. The relative share of the disease for the group 0-17 yr old is also very high-37.70%. The relative share for other subcategories, such as ischemic heart diseases and cerebrovascular diseases, for the whole population of the studied industrial region are very close- 9.95% and 7.85% respectively.

When considering subcategories for disease classification X- Diseases of the Respiratory System based on provided outpatient care, all three age groups suffer most of acute upper respiratory infections; 47.36 % of the population as a whole is diagnosed within this subcategory. Following are

diagnoses of acute bronchitis and acute bronchiolitis- 14.88%. The relative share of asthma (10.49%) and other diseases of upper respiratory tract (10.33%) are similar. Emphysema percentages are less than one.

Cerebrovascular diseases take the lead in morbidity for the population as a whole based on hospitalization (46.77%). Acute ischaemia of the heart is second, and this number (33.60%) includes acute myocardial infarction. The high relative share of these two subcategories is characteristic for the age group 18 yr and older, respectively cerebrovascular disease – 46.94% and ischaemic disease of the heart – 32.72%, and this is supported by existing literature. Of interest is the

high relative share of hypertensive disease in the age group 0-17 yr old (65.71%). This is related to obesity and physical inactivity in youth. The high percentage, however, contrasts the results of the other two age groups, (respectively: age group 18 yr and older – 2.73% and group population as a whole -3.08%). The relative share of ischaemic heart disease in patients 18 and older is 32.72% and in the population as a whole is 33.60%. Cerebrovascular disease accounts for 44.94% of cases in patients 18 and older and for 46.77% of cases in the population as a whole.

For the age groups 0-17 yr old, as well as the population as a whole, morbidity based on hospitalization for diseases of the respiratory system is led by pneumonias- 82.44% and 72.43%, respectively. Other subcategories of respiratory disease have a relatively low share in the boundaries of 1.10%-4.14%.

Analogous to determining the dynamic changes in atmospheric pollution of the studied industrial region, morbidity for the time period 2009-2013 is shown for the three age groups- 0-17 yr old, 18 yr and older, and the population as whole (Table 3).

Table 3: Morbidity of the population based on outpatient and inpatient care for the time period 2009-2013

Age groups	Morbidity based on outpatient medical care provided %	Morbidity based on inpatient medical care provided %
0-17 yr old	8.65	2.5
18 yr and older	2.6	16.5
Population as a whole	3.6	14.1

The highest percentage point is calculated for morbidity by hospitalization for the age group 18 and older- 16.5%. This can be explained by the aging of the population as a whole, more frequently arising health issues and the need for in-hospital treatment. The age group 0-17 yr old has seen a big drop (8.65%) in morbidity based on outpatient medical care provided for the period 2009-2013.

Discussion

Our results in the study area are confirmed by the data in the world literature. Most medical literature agrees that the respiratory system is considered to be the most sensitive organ system of the body to atmospheric pollutants just as children are the most sensitive members of a population (10-12). This is correlated to the immature immunity, high vulnerability and the body's predisposition to different respiratory diseases, especially in the early childhood years. In some cases, there is disruption of immune balance. It is therefore possible some infectious and parasitic diseases in children can be caused by air pollutants'

suppressive action on the production of immunoglobulin's (13-15).

The causes of the diseases of the genitourinary system can be correlated to the effect of the quality of drinking water. Numerous studies have supported our findings of atmospheric pollutants' effects on the optic analyzer (16-20).

Despite the low concentrations of atmospheric pollutants, the results of this study support existing literature in that pollutants affect respiratory health (21-23).

Hypertensive disease is a precursor for ischaemic heart disease and cerebrovascular disease in adolescence and adulthood. This relationship can be seen in the number of ischaemic heart disease and cerebrovascular disease cases. These diseases are indirectly associated with air pollution and climate. In their own studies, many authors have discovered a positive correlation between atmospheric pollutants and admission of patients with cardiovascular disease (24-26).

The observed period (2009-2013) reflects a decrease in atmospheric pollution and morbidity based on outpatient care and an increase in morbidity by inpatient care (hospitalization). This is

associated with the gasification of Stara Zagora City, the use of more environmentally-friendly fuels, the commissioning and effective operation of desulphurisation in Maritza East power complex.

Conclusion

From the atmospheric pollutants in the observed industrial region, the most important are sulfur dioxide, dust, nitrogen dioxide, lead aerosols, and hydrogen sulfide. This corresponds to the characteristics of current emissions. The registered outpatient care provided for the period 2009-2013 is highest for diseases of the cardiovascular system, the respiratory system, and the genitourinary system. The registered rate of hospitalization for the same period is for diseases of the digestive system, the cardiovascular system, respiratory system, and complications of pregnancy, birth and puerperium. The registered outpatient medical care provided to the population of the region as a whole, when broken down into subcategories of diseases of the circulatory system, is highest for hypertensive disease. The highest registering subgroup based on hospitalization is for cerebrovascular disease. For morbidity based on outpatient care, the leading subcategory of diseases of the respiratory system is acute upper respiratory infections, followed by acute bronchitis and bronchiolitis. Pneumonias are leading morbidity by hospitalization rates for the region's population as a whole. The observed period reflects a decrease in morbidity based on outpatient care provided and an increase in morbidity by hospitalization.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgment

The authors declare that there is no conflict of interests.

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