



Proceeding Paper

Application of AirQ+ Software in the Attica Region, Greece: The Hospitalizations and Work Days Lost Attributed to Air Pollutants [†]

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Abstract: The World Health Organization (WHO) has developed the AirQ+ software in order to estimate the magnitude of the impact of air pollution on health in a given population. In this study, the AirQ+ was applied to calculate the short-term effects attributed to PM_{2.5}, NO₂ and O₃ in the Attica Region, Greece. Based on the health endpoints handled by the AirQ+ software, we evaluated the impact of air pollutants on hospitalizations and work days lost. In 2015, 69,460 and 48,972 patients were admitted to the hospitals in the Attica Region due to circulatory and respiratory diseases, respectively. For the estimation of the attributable burden, the time-series of PM_{2.5}, NO₂ and O₃ concentrations for the year 2015 are used. The burden attributed to PM_{2.5} is 297 (55–546) and 441 (0–953) hospitalizations for circulatory and respiratory diseases, respectively. NO₂ and O₃ also contribute to the burden of hospitalizations for respiratory diseases. Specifically, 424 (271–576) and 381 (61–718) respiratory-related hospitalizations are attributed to NO₂ and O₃, respectively. An important effect of PM_{2.5} exposure also handled by the AirQ+ is work absenteeism. Based on health statistics for Greece, the number of self-reported work days lost per year due to illness are 14.7 days per employed person. The attributable burden of PM_{2.5} is 0.33 (0.28–0.38) work days lost (per employed person per year). In conclusion, the short-term effects of air pollution exposure has a great impact on human health.

Keywords: air pollution; PM_{2.5}; NO₂; O₃; air pollution health risk assessment; AirQ+ software



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1. Introduction

People are exposed to hazardous air pollutants in both outdoor and indoor environments. Outdoor (ambient) air pollution mainly consists of NO_x, SO₂, O₃, CO, H/C, Volatile Organic Compounds (VOCs) and Particulate Matter (PM) which are released from both natural and anthropogenic sources [1]. Generally, in urban environments, there are many man-made sources of air pollutants including exhaust and non-exhaust emissions from the road transport sector, emissions from the domestic sector such as residential heating and cooking, as well as power plants, manufacturing and industrial facilities and petroleum refineries [1,2]. All these processes affect the air quality and living environment. The air pollution is classified among the greatest environmental risk factors for human health. According to a WHO report, almost the entire global population (99%) breathes air that exceeds WHO air quality limits [3].

There is an overwhelming body of evidence demonstrating that the health effects of air pollution are serious. The study of health effects associated with PM exposure has been a major focus of research in the USA, Europe and Asia in recent decades [4,5]. Numerous epidemiological studies provide evidence of highly statistically significant associations between PM exposure and various health effects, such as mortality, cardiovascular and respiratory diseases, developmental disorders, effects on the nervous system and lung

cancer [4,5]. Restricted activity days, work absences and school absenteeism have also been reported to be associated with particle pollution [6].

Moreover, many studies estimated the health effects from the simultaneous exposure to NO_x and other pollutants (e.g., PM) emitted from the same sources. In recent decades the evidence linking NO₂ to health effects has grown significantly, showing that NO₂, independent of the presence of other air pollutants in the environment, is responsible for several health effects [7]. Epidemiological studies have found positive associations between NO₂ exposure and respiratory and cardiovascular diseases, hospital admissions, asthma prevalence and incidence and mortality [7].

In addition, O₃ is also an important secondary photochemical air pollutant with great dependence on meteorological factors. The effects it causes on human health are both acute and chronic. Typical symptoms following acute exposure to O₃ include coughing, nausea, throat irritation, chest pain and tightness, burning or discomfort in the chest and wheezing or shortness of breath [8]. Furthermore, O₃ exposure causes inflammation in the airways, reduces lung function and makes the lungs more susceptible to infections [8,9]. These effects can worsen lung diseases such as asthma, emphysema, chronic bronchitis and Chronic Obstructive Pulmonary Disease (COPD) [9]. Karakatsani et al. (2017) focused on Greek schoolchildren and correlated O₃ with airway inflammation and the increased frequency of respiratory symptoms [10].

Recognizing the need for further reduction in outdoor pollutant concentrations, the WHO updated its 2005 AQG (Air Quality Guidelines) in September 2021 (WHO, 2021) [11]. For example, the PM_{2.5} annual AQG level has been lowered from 10 µg/m³ to 5 µg/m³, while the 24 h AQG level for PM_{2.5} changed from 25 µg/m³ to 15 µg/m³.

The WHO Regional Office for Europe has recently developed the AirQ+ software tool in order to quantify the health burden and impact of air pollution. The version 2.2 of AirQ+ was released in March 2023 with improved functions for estimating the health effects of exposure to air pollutants [12]. In the Attica Region, the AirQ+ software has been applied by Moustris et al. (2017), Ntourou et al. (2017) and Ntourou et al. (2023) [13–15]. All these studies estimated the hospitalizations attributed to PM₁₀. Additionally, Begou and Kassomenos (2022) estimated the burden of mortality associated with long-term exposure to PM_{2.5} in the Attica Region [16].

In this study, the AirQ+ was applied to calculate the short-term effects attributed to PM_{2.5}, NO₂ and O₃ in the Attica Region, Greece. Given that the Attica Region is the major urban complex of Greece with a high population density and increased levels of air pollutants, the assessment of the impact of the air quality degradation is of paramount importance. The mortality and morbidity attributable to air pollution could be preventable through compliance with air quality legislation, regulations and standards. Therefore, we used the 2021 AQG level in order to perform a health impact analysis.

2. Materials and Methods

2.1. Study Area

The Attica Region has a total population of 3,792,469 residents based on the national census data of 2021. The air pollution in the Attica Region is the result of high population density and the accumulation of anthropogenic and economic activities [17,18]. The air pollution is often exacerbated by factors that favour the accumulation of air pollutants. These factors include the local topography of the region and adverse meteorological conditions such as the sea breeze development, temperature inversions, southern winds and low wind speed [17,18]. Also, the street canyons in the city centre influence the accumulation and dispersion of air pollutants [17,18].

2.2. Air Pollution Data

The 24 h concentrations of air pollutants were collected from all the available Air Quality Monitoring Stations (AQMS) of the National Air Pollution Monitoring Network (NAPMN) in the Attica Region, from the 1 January 2015 to the 31 December 2015. The

NAPMN is operated by the Air Quality Department of the Ministry of Environment and the air pollution data are available online on the Ministry’s official website (www.ypen.gov.gr (accessed on 10 May 2023)).

2.3. Hospital Admissions Data

The annual number of hospital discharges were obtained by a survey on the in-patient hospital care of the Hellenic Statistical Authority for the year 2015 [18]. Hospital discharge rates measure the number of patients who leave a hospital after staying at least one night. The survey data were compiled from 275 hospitals/clinics, from which 36.4% of them are located in the Attica Region. The survey recorded data on the number of patients discharged by category of disease and place of permanent residence, their demographic characteristics and the disease diagnosed, in line with the International Statistical Classification of Diseases and Related Health Problems (ICD 10) [19]. In this study, we used the annual number of hospital discharges in the Attica Region for the year 2015. We used the annual number of hospital discharges for diseases of the circulatory system (ICD 10: Code I00–I99) and diseases of the respiratory system (ICD 10: Code J00–J99).

3. Results and Discussion

3.1. Air Pollutant Concentrations

For the year 2015, the annual mean concentrations of PM_{2.5} and NO₂ are shown in Table 1. The annual mean PM_{2.5} concentration varied between 10.3 ± 4.6 µg/m³ at AgP AQMS and 21.2 ± 14.5 µg/m³ at Pir AQMS. As for the NO₂ concentration, Ari AQMS and Pir AQMS registered the highest annual values, 52.5 ± 15.7 µg/m³ and 51.7 ± 19.0 µg/m³, respectively. Figure 1 shows the time series of the maximum daily 8 h O₃ concentrations for the year 2015. The 8 h O₃ mean of 100 µg/m³ was exceeded for 30–46% of the days at the AQMS located in suburban areas (AgP, Lyk and Thr).

Table 1. Annual average and standard deviation (±SD) of PM_{2.5} and NO₂ concentrations for the year 2015 at the AQMS in the Attica Region.

Air Pollutant	Aristotelous Street (Ari)	Piraeus (Pir)	Elefsina (Ele)	Agia Paraskevi (AgP)	Lykovrisi (Lyk)	Thrakomakedones (Thr)
PM _{2.5}	19.6 (± 15.2)	21.2 (± 14.5)	16.1 (± 7.9)	10.3 (± 4.6)	16.5 (± 14.0)	12.8 (± 4.0)
NO ₂	52.5 (± 15.7)	51.7 (± 19.0)	23.7 (± 8.6)	11.2 (± 6.1)	18.5 (± 11.0)	8.4 (± 5.2)

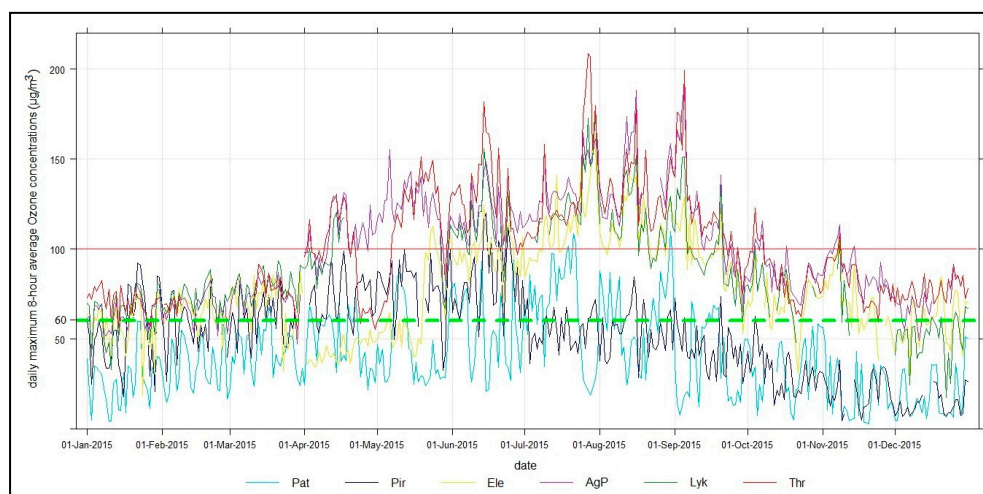


Figure 1. Maximum daily 8 h O₃ concentrations (µg/m³) for the year 2015 at the AQMS in the Attica Region. The red line corresponds to the WHO maximum daily 8 h mean limit value of 100 µg/m³, while the dotted green line corresponds to the WHO peak season limit value of 60 µg/m³.

3.2. AirQ+ Software Application

For the Health Impact Assessment (HIA) of the health effects associated with the short-term exposure to PM_{2.5}, NO₂ and O₃, the AirQ+ software requires the air quality data of the region, the population at risk and the health statistics. For this purpose, the air pollutants concentrations presented in Section 3.1 were used. The annual number of hospital discharges for diseases of the circulatory and respiratory systems for the year 2015 are shown in Table 2. According to the Hellenic Statistical Authority for the year 2015, the estimated population in the Attica Region was 3,822,843 residents.

Table 2. Annual number of hospital discharges for diseases of the circulatory and respiratory systems in Greece and the Attica Region, for the year 2015.

Hospital Discharges	ICD 10: Code A00–Z99	ICD 10: Code I00–I99	ICD 10: Code J00–J99
Annual hospital discharges (in Greece)	2,554,490	237,561	152,725
Annual hospital discharges (in the Attica Region)	482,789	69,460	48,972

Table 3 shows the estimated attributable proportion and the number of hospital admissions (of the total population and of the population at risk) for diseases of the circulatory and respiratory systems due to exposure to air pollutants. The exposure to PM_{2.5} contributed to 297 (55–546) hospitalizations for respiratory diseases and 441 (0–953) hospitalizations for diseases of the circulatory system. Also, the exposure to NO₂ and O₃ resulted in 424 (271–576) and 381 (61–718) hospitalizations for diseases of the respiratory system.

Table 3. Hospital admissions for diseases of the circulatory and respiratory systems in the Attica Region, for the year 2015.

Diseases of the circulatory system	PM _{2.5} (cut-off value: 15 µg/m ³)			NO ₂ (cut-off value: 25 µg/m ³)			O ₃ (cut-off value: 60 µg/m ³)		
	Central	Lower	Upper	Central	Lower	Upper	Central	Lower	Upper
Estimated attributable proportion	0.43%	0.08%	0.79%						
Estimated number of hospital admissions	297	55	546						
Estimated number of hospital admissions per 100,000 population at risk	7.78	1.45	14.28						
Diseases of the respiratory system	Central	Lower	Upper	Central	Lower	Upper	Central	Lower	Upper
Estimated attributable proportion	0.9%	0%	1.95%	0.87%	0.55%	1.18%	0.78%	0.12%	1.47%
Estimated number of hospital admissions	441	0	953	424	271	576	381	61	718
Estimated number of hospital admissions per 100,000 population at risk	11.54	0	24.92	11.09	7.10	15.06	9.97	1.59	18.78

The estimated number of attributable cases is usually converted to the attributable cases per 100,000 population at risk. Thus, PM_{2.5} exposure resulted in 7.78 (1.45–14.28) and 11.54 (0–24.92) circulatory-related and respiratory-related hospitalizations per 100,000 population at risk, respectively. As for NO₂ and O₃, the respiratory-related hospitalizations were 11.09 (7.10–15.06) and 9.97 (1.59–18.78) per 100,000 population at risk, respectively.

The results of this study are comparable to previous studies evaluating hospitalizations with the AirQ+ software. Moustris et al. (2017) applied the AirQ+ 2.2.3 model in the Attica Region in order to calculate the annual number of hospital admissions for respiratory diseases due to the exposure to PM₁₀ concentrations during a 13-year period (2001–2013) [13]. They found that the hospitalizations ranged from 20 (in the suburban area) to 40 (in the city centre) per 100,000 inhabitants [13].

As for the estimation of the work days lost due to the exposure to PM_{2.5}, the OECD (Organisation for Economic Co-operation and Development) health statistics were used [20]. In Greece, the self-reported absence from work days due to illness resulted in 14.7 days lost per employed person per year (in 2014) [20]. Based on the labour force survey from ELSTAT, the total number of employed people in the Attica Region were 1,336,000 for the

year 2015 [21]. As we can see from Table 4, the number of work days lost attributed to PM_{2.5} exposure were 0.33 (0.28–0.38) days per employed person in 2015.

Table 4. Work days lost due to PM_{2.5} exposure.

	Central	Lower	Upper
Estimated attributable proportion	2.24%	1.88%	2.6%
Estimated number of work days lost in the total number of employed people	439,915	370,191	510,918
Estimated number of work days lost per 100,000 employed people	32,928	27,709	38,242
Estimated number of work days lost per employed person	0.33	0.28	0.38

4. Conclusions

In this study, an analysis was performed with the AirQ+ software in order to estimate the hospitalizations and work absenteeism attributed to short-term exposure to air pollutants. In the Attica Region, the burden attributed to PM_{2.5} was 297 (55–546) and 441 (0–953) hospitalizations for circulatory and respiratory diseases, respectively. NO₂ and O₃ also contributed to 424 (271–576) and 381 (61–718) respiratory-related hospitalizations, respectively. As for work absenteeism, PM_{2.5} caused 0.33 (0.28–0.38) work days lost (per person per year).

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