Original Article

The effects of environmental pollution on the respiratory system of children in Western Macedonia, Greece

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Summary. The indoor and outdoor environmental pollution effects on the respiratory system of 3,559 children aged 9-12 were studied. It was a cross-sectional and interlocal (geographical differentiation) study. The research was conducted during the period between 2000-2001 in five cities of Western Macedonia and more particularly: 1046 children from Ptolemaida, 1249 children from Kozani, 466 from Florina, 419 from Kastoria and 379 from Grevena. The study was performed by means of a questionnaire for the detection of respiratory diseases during childhood, plus spirometry and rhinomanometry measurements. The diachronic quantitative analysis of environmental pollutants was conducted by The Laboratory of Physics of the Atmosphere of the Aristotle University of Thessaloniki.

The environmental pollution was found to have a detrimental effect on the respiratory system of children, mainly attributable to the occurrence of rhinitis and infectious bronchitis. The highest prevalence of rhinitis (40.3%) and infectious bronchitis (12.1%) was observed in Ptolemaida, which is a highly polluted region, whereas the lowest (21.2% and 6.7%, respectively) was seen in Grevena, a non-polluted area. As for the indoor pollution, maternal smoking was found to increase the prevalence of respiratory problems in children. Finally, the father's educational level and a past history of nursery school attendance increase the prevalence of respiratory diseases during childhood.

Keywords: children, asthma, rhinitis, epidemiology, pollution, Greece

Introduction

It has been previously shown that a history of respiratory problems during childhood is correlated with an increased risk of pathologic respiratory function and chronic obstructive pulmonary disease during adulthood [1]. It seems that the respiratory system of infants is extremely sensitive to nonspecific stimuli [2,3], and this hyper-reactivity evolves inversely to the age of its debut [4,5]. Consequently, the protection of a child's respiratory system ensures healthy lungs during adulthood.

It is known that high levels of environmental pollution affect the morbidity and mortality from respiratory diseases. However, the effect of long-lasting exposure to "accepted' pollution limits is unknown. The epidemiological studies conducted worldwide focus mainly on adults in whom both smoking and occupational exposure complicate the environmental pollution effects [6]. It seems that the exposure to road traffic pollution is associated with a higher risk for a sensitization to pollen and this could possibly be interpreted as an indication for interactions between pollen and air pollutants that may enhance the development of respiratory disorders [7]. Likewise, moderate levels of air pollutants exacerbate rhino-conjunctivitis symptoms in pollen-allergic individuals [8].

It is also known that the respiratory system is affected by several other factors such as the socioeconomic status [9], the number of family members in relation to

residencial space [8], the existence and nature of respiratory disease of co-habitants [10] and their smoking habits [11,12], and the kind of the heating and cooking sources [13].

The increased levels of air pollution augment the rate of respiratory symptoms and illnesses among children even in countries with moderate average concentration of pollutants [14]. In Greece, the epidemiological investigations of respiratory diseases during childhood are few [15,16] and limited to the study of respiratory function parameters or the occurrence of symptoms in relation to the environmental pollution.

The objective of this study was the investigation of the effect of indoor and outdoor environmental pollution on the respiratory system of children aged 9-12. We studied children living in the cities of Western Macedonia, Greece (Ptolemaida, Kozani, Florina, Kastoria and Grevena); cities presenting significant differences as to the type and level of environmental pollution and as to the prevailing socioeconomic conditions.

Materials and Methods

1. Subjects

The study, performed during school year 2000-2001, included a total 3,559 children of the last three courses of the primary schools of Western Macedonia; City of Ptolemaida (1046 children), Kozani (1249 children), Florina (466 children), Kastoria (419 children) and Grevena (379 children).

The cities of Kastoria and Grevena are considered as the less polluted ones because of their low industrial growth index. On the contrary, Ptolemaida, Kozani and Florina are industrial regions par excellence.

A number of 1710 boys and 1849 girls living for at least five years in the region under examination were studied. All children were submitted to spirometry, rhinomanometry and they were also provided with a questionnaire.

a. Questionnaire

The questionnaire used was based on the Ferris [17] questionnaire with some additions regarding symptomatology of the upper respiratory system. The questionnaire's adequacy has been proven in various epidemiological investigations conducted in children [15,18]. It included questions on demographic data of the children, educational level of the parents, living conditions at home, factors of domestic pollution (smoking habits, source used for heating and cooking), any respiratory diseases of the family members and the presence of pets. Through appropriate questions, it investigates the history and symptomatology of the upper and the lower respiratory system in children, any allergic reactions and the history of infectious diseases during childhood.

The questionnaire was distributed to the children and was filled in by the parents and collected one week later.

b. Spirometry

Spirometric measurements were performed with the use of a Vitalograph calibrated dry spirometer. After explaining the purpose and the spirometry method, the children performed at least three maximum efforts [19].

c. Rhinomanometry

Following the method of anterior rhinomanometry [20], nasal resistances and flows were defined with the use of a Rhinotest mP 500 rhinomanometer. Measurements were conducted at 150 Pascal (Pa) and flows were measured at ml/sec.

2. Environmental pollution study

Monitoring of environmental pollution in the Eordea valley was carried out by the Laboratory of Physics of the Atmosphere, Aristotle University of Thessaloniki. The study provided information about the cities of Ptolemaida, Kozani and Florina. No measurements were available for the cities of Kastoria and Grevena which in our study were considered less polluted because of their nonindustrial status.

3. Statistical analysis

The analysis of the results was performed with the statistical packet SPSS with the independency-homogeneity test χ^2 and with the Hierarchical Logistic Linear Models technique. The odds ratio (OR) and the relative risk (RR) were also calculated.

Results

A. Environmental pollution study

The main pollutant in the Eordea valley, where the cities of Ptolemaida, Kozani and Florina are situated, are the suspended particulates, mainly due to the surface mining of lignite and the power steamed stations of the Public Electrical Power Corporation. The concentrations of total suspended particulate within the valley are, in general, high. The maximum TSP concentrations are observed in the city of Ptolemaida (mean value 132 $\mu g/m^3$, max 380 $\mu g/m^3$) and they decrease with increasing distance from city centre. At all station values over the limit established by the World Health Organization (WHO) for the suspended particulates (120 $\mu g/m^3$) are daily detected [21]. Values above the limit of 250 $\mu g/m^3$, which is the alert value for the cities of Athens and Thessaloniki, are observed in many stations during several days each year. Sulfur dioxide (SO2) does not constitute a significant factor of air pollution since the annual concentrations are lower than the limit reference values. Grain size distribution analysis of all samples showed that the inhaled fraction (<5 μm) of fly ash is always low, i.e. 9% on average.

For the other two cities, Grevena and Kastoria, there are no measurements, since they are situated in non industrial regions (Table 1).

Table 1. The prevalence of the upper and lower respiratory system diseases in children in five cities and their respective pollution levels.

	Ptolemaida N: 1046	Kozani N: 1249	Florina N: 466	Kastoria N: 419	Grevena N: 379	Total N:3559	RR	p
Rhinitis%	40.3	35.2	39.2	30.8	21.2	35.6	1.9	<0.001
Asthma%	6.9	5.4	6.2	8.4	6.3	6.4	1.5	NS
Infectious bronchitis%	12.1	8.1	10.1	9.7	6.7	9.6	1.8	<0.01
Acute bronchitis%	17	12.3	14.1	13.3	7.1	13.5	2.4	<0.001
TSP μg/m^3								
Mean	132	88	56	–	–			
Max	380	299	272	–	–			
PM10 μg/m^3	86.3	64.2	58.3	–	–			
SO2 μg/m^3								
Mean	3	7	8	–	–			
Max	14	13	70	–	–			

B. Questionnaire analysis

Based on the answers of the questionnaire, it was concluded that the prevalence of rhinitis presents an uneven distribution among the 5 cities (p<0.001). The relatively highest risk is detected in Ptolemaida and the lowest one in Grevena, RR=1.9.

Positive answers that were given regarding demonstration of dyspnea, cough or wheezing in incidents without any symptoms of cold in children and after intensive exercise, were considered indicative of asthma. The prevalence of asthma also presents an uneven distribution among the five cities reaching the highest rate in Kastoria (8.4%) and the lowest (5.4%) in Kozani (RR=1.5).

Infectious bronchitis, i.e. cough and expectoration for a week or more was reported by 12.1% of the children of Ptolemaida, and 6.7% in Grevena (RR=1.8). At least one episode of acute bronchitis was included in the history of 17% of the children of Ptolemaida and 7.1% of the children in Grevena (RR=2.4) (Table 1).

The prevalence of upper and lower respiratory system diseases in children among the five cities varied according to the geographical location. With regard to rhinitis, infectious and acute bronchitis, statistically significant differences were found; however, such differences were not detected for bronchial asthma.

The examination of the children regarding the occurrence of various types of allergy in relation to asthma showed that 17.9% of the children with food or skin allergy presented with asthma, in comparison with 4.2% of those without atopic manifestations (p<0.001). According to our study, the presence of pets is a predisposing factor for the development of asthma (Table 2).

Our analysis of the pollution factors in the domestic environment in relation to the respiratory problems of the children, showed that 2053 (58.5%) out of 3512 of the fathers and 1373 (38.8%) out of 3539 of the mothers were smokers. Smoking by the father did not seem to affect the prevalence of the children's respiratory problems (bronchial asthma and rhinitis), whereas we

Table 2. Relations between atopy, presence of pets and prevalence of bronchial asthma and confidence limits (95% Confidence Interval)

		N	Asthma	%	OR	95%CI	P
Atopy	**Yes**	705	126	17.9	5.93	4.46-7.90	
	No	2.854	101	3.5	1.00	Ref	<0.001
Pets	**Yes**	860	61	7.1	1.16	0.85-1.60	
	No	2.699	166	6.2	1.00	Ref	NS

Table 3. Relationship between prevalence of pulmonary diseases and domestic pollution

Smoking of father	N	Pulmonary disease	%	OR	95%CI	P
Yes	2.053	613	29.8	1.05	0.90-1.22	
No	1.506	435	28.9	1.00	Ref	NS
Smoking of mother						
Yes	1.375	454	33	1.32	1.14-1.53	
No	2.184	594	27.2	1.00	ref	p<0.001
Heating						
Radiators Accumulators	3.288	964	29.3	1.00	Ref	NS
Wood-petroleum Gas	271	84	31	1.08	0.82-1.43	
Cooking						
Electrical cooker	3.495	1.028	29.4	1.00	Ref	NS
Gas	64	20	31.2	1.09	0.62-1.91	

found a close relationship between pulmonary diseases, which was documented in 33% of the children, and maternal smoking (Table 3).

The power and source used for heating or cooking did not affect the prevalence of pulmonary diseases (Table 3).

According to the results shown in table 4, the educational level of the father seems to play an important role in the occurrence of pulmonary disease (p<0.05), and likewise the attendance to nursery school (p<0.001).

Finally, in order to define their financial status index, families were asked about the power source they use

Table 4. Relationship between prevalence of pulmonary disease and living standards.

	Living standards Educational level of the father	N	Pulmonary disease	%	OR	95%CI	P
N	Primary	408	142	34.8	1.00	ref	
3559	Secondary	2.366	683	28.9	0.75	0.60-0.95	p<0.05
	Higher	785	223	28.4	0.74	0.57-0.96	
	Nursery school						
N	Yes	569	205	34.4	1.32	1.03-1.60	
3559	No	2.963	843	28.4	1.00	Ref	p<0.001
	Economic potential						
N	Low	765	241	31.5	1.13	0.95-1.35	NS
3559	High	2.794	807	28.9	1.00	ref	

Table 5. Spirometry findings (as percentage % predicted) and nasal flows (ml/sec)

	FVC% pred.	FEV_1% pred.	FMF% pred.	FEV_1/FVC%	FL.SUM
Ptolemaida	86.9±11.6	89.2±12.4	90.7±119.8	91.7±5.7	479±214
Kozani	89.8±12.2	91±12.8	92.8±20.3	91.9±5.7	533±285
Florina	85.9±11.1	89.9±12.2	91.7±28.9	92.1±5.5	515±220
Kastoria	85.9±11.1	89.8±12.1	91.6±19.7	92.7±5.3	598±156
Grevena	88.2±12.1	91.2±12.9	92.8±19.7	92.1±4.9	689±165

for heating, i.e. diesel, wood or gas and whether two or more people sleep in the same room with the child. Based on the questionnaire analysis regarding the above parameters (Table 4), we found an increase of pulmonary diseases in children living in unfavorable economic conditions, a difference, however, that did not attain statistical significance.

Table 5 provides measured values of Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), FEV1/FVC% ratio, Forced Expiratory Flow 25-75% (FEF25-75%) and rhinomanometry.

Spirometry values present no differences, whereas nasal flows present statistically significant differences ($p<0.001$) among the cities of Ptolemaida, Kozani and Florina, on one hand, and Kastoria and Grevena, on the other.

Discussion

Children living both in heavy polluted and in non-polluted regions were enrolled in the study. The findings of this study agree with the literature, i.e. symptoms from the upper and lower respiratory system are more frequent in children living in an air polluted environment.

The difference between polluted and non-polluted areas was mostly related to the suspended particles in the cities of Ptolemaida, Kozani and Florina with levels almost constantly higher than the limits established by the WHO.

Air pollutants, and more specifically suspended particles, are released through the inhaled air passing through the upper airways (nose) and thus leading to the development of chronic infection of the airways [22-24].

The high prevalence of "chronic rhinitis" and low nasal flows observed mostly in Ptolemaida, Kozani and Florina, may be due to the mechanism described above. In the above three cities and in Kastoria, we observed an increased prevalence of acute bronchitis and particularly in Ptolemaida the occurrence of infectious bronchitis. These findings may be attributed to the fact that the exposure to high air pollution concentrations increases the sensitivity to infections due to the impairment of mucociliary clearance and macrophage activity [25].

Bronchial asthma showed the highest prevalence in Kastoria and the lowest one in Kozani. This could be due to the higher socio-economic level of the inhabitants of Kastoria compared with those of the other cities. The pathogenetic relationship between bronchial asthma and air pollution is not known. It is believed that the common air pollutants studied do not cause asthma, however they can lead to episodes of bronchospasm in subjects with bronchial hyperreactivity. The SCARPOL study provided evidence that while the symptom rates of chronic cough and bronchitis augment with increasing levels of air pollution, there is no association between long-term exposure to air pollution and classic asthmatic and allergic symptoms and illnesses [14].

The main pollutants of the domestic environment, when wood, diesel or gas are used for heating and cooking, are CO and NO2. A slight but important relationship between NO2 increased levels indoors and respiratory symptom prevalence has been reported [26-28]. In our study we found that the use of gas, diesel or wood for heating does not increase the prevalence of symptoms from the respiratory system.

Cigarette smoke is considered to be an important indoor pollutant and a predisposing factor for infections [29] and increased bronchial reactivity [30,31], and affects the development of the children's respiratory system [32]. Nevertheless, in this study the smoking habit of the father was not found to lead to increased respiratory symptoms in the child. However, an important effect of smoking by the mother was found. These findings agree with those of the SCARPOL study where children exposed to environmental tobacco smoke at home, and particularly to maternal smoking, suffered more often from respiratory symptoms [12].

Theoretically, the educational level of the parents and the living standard of the family play an important role in the prevalence of respiratory system disorders, in the sense that children who receive increased parental attention and do not share bedroom facilities with others (a predisposing factor for the transmission of infectious respiratory diseases) may be protected. We found significant differences regarding the occurrence of respiratory diseases in children from families with a lower living standard and educational level. An important question relates to the occurrence of frequent

pulmonary infections in children because of crowding in nursery schools from an early age. In our study, children who were hosted in nursery schools during infancy and early childhood, were observed to present pulmonary diseases more often.

In general, the questionnaire analysis for the investigation of respiratory diseases poses some intrinsic difficulties. Answers were given based on the memory and sensitivity of the parents. However, our study also used completely objective indexes, such as spirometry and rhinomanometry. Indeed, mean FEV1 was lower in the children of Ptolemaida and higher in the children of Grevena. Moreover, rhinomanometrically, low nasal flows were recorded in the cities of Ptolemaida, Kozani and Florina; three cities with particulate pollution, compared to Kastoria and Grevena. It had been reported that the repetition of respiratory infections during childhood is related to a high diminution rate of the respiratory function during adult life since the effect of smoking is added [33]. The consequences of the findings of this investigation on the respiratory system status during adulthood are not easily predictable. The long-term follow-up of the respiratory function of these children could eventually give an answer to the above question and should be the aim of further investigation.

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