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RESPIRATORY HEALTH OF CHILDREN AT SCHOOLS NEAR A FERTILIZER PLANT

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In an investigation carried out over a six-month period in 1990 and 1991 the effect of exposure to possible air pollutants from a fertilizer plant on the respiratory health of preadolescent children was estimated. Data about children and their home environment were collected from physical measurements at school and from a questionnaire which was administered to the parents. Simultaneously, air pollution measurements were undertaken. The school children were placed into two groups according to the distance of the school from the plant. The incidence of acute respiratory disorders was 24%. The mean values of forced expiratory volume (FEV_1) were slightly and insignificantly lower in exposed children. When the confounding factors were taken into account, the prevalence of symptoms at schools within 1–3 km from the fertilizer production was marginally higher. These findings give no support to the hypothesis that fertilizer emissions cause respiratory disease in children although an adverse effect in a few sensitive children cannot be ruled out.

Key terms:
air pollutants, lung function tests, phosphate fertilizer plant

Exposure to particulate and gaseous compounds emitted from the fertilizer industry is expected to affect children's physical development. Several studies carried out in the surrounding communities showed an association between exposure to irritants and respiratory impairments (1–3); other studies failed to establish a significant association (4, 5).

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The purpose of this paper is to report the results of a study conducted in the vicinity of a phosphate fertilizer plant. Pollutants of major interest were ammonia, nitrogen oxides and fluorides. Fluorides were released to the atmosphere by drying and acidulation of the F-containing phosphoric rock in the manufacture of superphosphate fertilizer and phosphoric acid (6). The effect of exposure to these pollutants on the incidence of respiratory illnesses and on ventilatory performance of school children was investigated.

SUBJECTS AND METHODS

In 1990–1991 a survey of respiratory symptoms and lung function tests were performed including all second-grade children in the exposed and control areas. The study group comprised 164 second graders aged 8–10 years who attended two schools located within 1–3 km from the fertilizer plant, in the area expected to be polluted. The control group consisted of 59 second graders of similar socioeconomic status from the school in a small neighbouring town, 22 km away from the plant. Data about the children and their home environment were collected by physical measurements at school and from a questionnaire which was administered to the parents.

Anthropometry was performed according to the technique recommended by the IBP (7). For lung function measurements a Vicatest-5 spirometer, Mijnhardt, Holland was used, with the subject in the standing position, without a noseclip. After detailed instructions were given, tests were performed at least three times for each child and the highest reading was taken to be the final result. Ventilatory performance was done once weekly at the same day each week and at approximately the same time (between 9 and 11 a.m.) in November and May of the 1990/91 school year. Children did not perform lung function tests if they had a history of respiratory illness. Their ventilatory volume values were average values of three instead of four measurements.

The questionnaire administered to parents allowed to obtain information about household exposure i.e. density of habitation (person/room), use of gas stove and parental history i.e. education level (elementary <=8 years; above elementary >8 years) and smoking habit. The data about respiratory illnesses were collected by the method of *Shy and co-workers* (8) on postcards which the parents received every two weeks from November 1990 to May 1991.

Respiratory illness was defined as a positive answer to the question: "Has anyone in the family been ill with a respiratory disease over the last fortnight?". The answers were standardized as the number of doctor diagnosed respiratory illnesses and respiratory illnesses that kept the child at home for a period of three days or more.

Ammonia, fluorides and nitrogen oxides were selected for measurement as emission markers. These pollutants were determined in 24-hour air samples collected at three sampling sites: in two schools in the plant area and in one school in the control area. The samples were collected in the period from November 1990 to June 1991. Measurements of ammonia concentrations in ambient air were carried out spectrophotometrically by the Nessler method, fluorides were determined by means of an electrostatic precipitator followed by a standard impinger (9) and nitrogen(IV)oxides were measured by the Levaggi modification of the Hochheiser method (10).

Descriptive statistics was calculated using the Complete Statistical System 3.1 package on a PC/AT 286 IBM compatible computer. The differences between the children attending the schools near the source of pollution and the children who did not were determined by means of univariate and multivariate ANOVA models. The role of different risk factors in determining respiratory illness was established using multiple regression models, in comparison with children without these risk factors (11).

To assess the joint effect of several exposure factors multiple regression analyses were conducted. The multiple logistic regression was applied to determine whether the transformation would be more discriminating for the various groups. As the evaluation showed no differences between the transformed and non-transformed analyses, the results were based on the non-transformed data. The study confirmed that the linear regression approach to relate pulmonary function variables to anthropometric measurements was fully justified if narrow age groups were considered.

RESULTS

Two hundred and twenty-three school children were interviewed. The age and height distribution for exposed and control children was not significantly different. The children from the control area had lower weight and lived in larger homes (Table 1).

Forty-five fathers (20%) were industrial and agricultural workers and 80% were office workers and college graduates.

A total of 149 children (67%) lived in families that included smokers. The number of family members per room was 2.1 in the exposed and 1.65 in the control group of children. Forty-six per cent of the examined flats had central heating, 30% used gas for heating, 21% used oil or wood and 35% depended on different combined sources of energy.

The mean values of air pollution which had been recorded at sites around the schools were below maximum allowable concentrations and threshold limits for ambiental pollution (12, 13). The daily fluctuations, however, particularly in the case of ammonia, happened to exceed these values. Only small differences were found in the observed mean values of air pollution between the schools closer to the pollution source (exposed area) and the more distant school (control area) (Table 2).

Table 1 *Characteristics of examined school children*

	Exposed area (n=164) $\bar{X}$	Control area (n=59) $\bar{X}$	P
Age (yr)	8.70	8.72	NS
Height (cm)	130.5	129.0	NS
Weight (kg)	29.6	26.6	<0.001
Sex			
boys (%)	53	59	NS
girls (%)	47	41	
Parental education level			
elementary (<8 yrs)	15	31	NS
above elementary (>8 yrs)	85	69	
Parental smoking habit			
no	30	42	NS
yes	70	58	
Density of habitation (person/room)			
0–2	47	73	<0.001
2+	53	27	
Gas heating			
no	71	69	NS
yes	29	31	

Table 2 *Levels of air pollution (μg/m³) mean values (ranges)*

	Outdoor atmosphere		Indoor atmosphere		
	exposed	control	exposed	control	TLV μg/m³
Ammonia	83 (4–420)	83 (2–237)	119 (51–352)	102 (19–206)	80
Fluorides	0.63 (0.02–4.50)	0.49 (0.02–2.69)	0.37 (0.02–4.36)	0.30 (0.02–2.46)	1
Nitrogen (IV)oxide	11 (3–48)	12.5 (2–46)	9.5 (10–30)	8.5 (1–24)	40

TLV– threshold limit value for ambiental pollution

Table 3 shows the prevalence of respiratory symptoms in exposed and control areas over a six-month period according to sex. In the investigated period the incidence of acute respiratory disorders was 24%. The magnitude of difference between school children living in the vicinity of the plant and those from the non-industrial area was not observed to be statistically different. Crowding and gas heating showed no consistent effect on the reported symptoms (Table 3).

Exposure to parental smoking was associated with more respiratory symptoms (28% in children of smokers against 19% in children of non-smokers), although the differences were not statistically significant.

Table 3 *Prevalence of symptoms in school children in the exposed and control areas over a six-month period*

	Boys (n=122) %	Girls (n=101) %	Total (n=223) %
Exposed (n=164)	28	23	25
Control (n=59)	24	18	22

The results of multiple logistic models which accounted for independent effects of other risk factors (parental smoking, parental level of education, use of gas stove for heating, density of habitation) are shown in Table 4. The relative risk estimates for the reported respiratory symptoms in the exposed versus control group after adjusting for confounding variables were 1.28 for boys and 1.21 for girls (Table 4).

Table 4 *Odds ratios (OR) and 95% confidence interval (CI) for reported respiratory symptoms in the exposed versus control group*

	OR (95% CI)	adjusted OR (95% CI)
Boys	0.95 (0.397–2.270)	1.28 (0.510–3.206)
Girls	1.42 (0.427–4.719)	1.21 (0.359–4.068)

The odds ratio for respiratory illness was adjusted for possible confounding factors by multiple regresion models: parental smoking: 0 – no, 1 – yes; level of parental education: 0 – elementary, 1 – above elementary; use of natural gas heating fuel: 0 – no, 1 – yes; density of habitation: 0 – < 2, 1 – > 2. The odds ratios are not statistically significant.

The mean values of forced expiratory volume in the first second (FEV_1) adjusted for age, height and weight are reported in Table 5. The values were slightly and insignificantly lower in exposed children. A fairly constant sex difference was observed with boys showing average values 70 ml larger for the same age and height in the exposed area and 100 ml larger in the control area. There was a slight positive association between ventilatory function (FEV_1) and parental smoking in both sexes. A weak negative association was established between FEV_1 values and density of habitation for both sexes and between FEV_1 values and gas heating for boys (Table 5).

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A step-down multiple linear regression model was used to assess the effect of a number of variables on the rate of reported respiratory symptoms and on the FEV_1 value (Table 6).

According to multiple regression analysis the level of parental education could explain approximately 2.6% of the variability of the rate of respiratory illnesses; parental smoking habit and density of habitation accounted for 0.9% and 0.8%, respectively (Table 7).

Table 5 *Mean FEV_1 measurements (l) adjusted for age, height and weight summarized by covariates*

	Boys (n=122)	Girls (n=101)
Exposed area	1.70 (87)	1.63 (77)
Control area	1.74 (35)	1.64 (24)
Parental education level		
elementary (<=8 yrs)	1.70 (22)	1.66 (23)
above elementary (>8 yrs)	1.71 (100)	1.66 (28)
Parental smoking habit		
no	1.70 (43)	1.64 (31)
yes	1.74 (79)	1.66 (70)
Density of habitation (person/room)		
0–2	1.73 (77)	1.70 (43)
2+	1.71 (45)	1.67 (58)
Gas heating		
no	1.73 (84)	1.68 (68)
yes	1.70 (38)	1.69 (33)

Sample sizes are given in parentheses

Table 6 *Factors related to the respiratory symptoms rate (summary of stepwise analysis)*

Factor	Regression coefficient	R-square change	P
Parental education level	0.1614	0.026	0.02
Density of habitation	– 0.1064	0.008	0.13
Parental smoking	0.0993	0.009	0.15
Gas heating	– 0.0721	0.005	0.30

Multiple r = 0.23; total subjects in multiple regression analysis 223 (parental education level: 0 – elementary, 1 – above elementary; density of habitation: 0 – <= 2 person/room, 1 – >2 person/room; parental smoking: 0 – no, 1– yes; gas heating: 0 – no, 1 – yes; respiratory symptoms: 0 – absent, 1 – present)

The factors included in the model explained 57% of the total variation of FEV_1, with age and height alone accounting for 55.5% of the variation. Of the remaining factors, the school residence as measure of exposure accounted only for 0.4% and parental smoking for 0.4% of the variance of FEV_1.

Table 7 *Factors related to the FEV_1 values (summary of stepwise analysis)*

Factor	Regression coefficient	R-square change	P
Height (cm)	0.6471	0.527	0.00
Sex	0.1590	0.025	0.00
Weight (kg)	0.1279	0.008	0.06
Parental smoking	0.0647	0.004	0.19
School residence	0.0696	0.004	0.16

Multiple r = 0.76; total subjects in multiple regression analysis 223 (sex: 0 – girls, 1 – boys; parental smoking: 0 – no, 1 – yes; school residence: 0 – <3 km away from the fertilizer plant, 1 – >20 km away from the fertilizer plant)

DISCUSSION

Respiratory complaints relating to airborne industrial emissions are not uncommon (14, 15). Less is known about the effects of industrial air pollution at a young age (16–18), but the association of childhood respiratory disease with passive smoking suggests that children may be unusually susceptible to airborne pollutants (19). Evidence that acute respiratory health in children is affected by industrial air pollutants near a fertilizer production has been reported by few investigators (1, 2, 20). Children may be particularly sensitive to substances with effects on the lung (21, 22). Ammonia, fluorides and nitrogen oxides as environmental irritants may produce respiratory symptoms that are inherently reversible and may provide clues to early detection of abnormalities or identification of sensitive population subgroups.

The results of this study show that there was no clear association between exposure to air pollutants from the fertilizer production plant and parental reports of their children's respiratory symptoms. Boys had a higher illness rate than girls. The frequency of respiratory illnesses was consistent with that reported by some other investigators (5, 23). The evidence suggests that industrial emissions from the fertilizer plant produce a slight effect, if any, upon the health of nearby residents. The nature and frequency of respiratory complaints are not unique to measured irritants; they reflect many of the minor childhood illnesses and may be expected to confuse comparison.

After adjusting for confounding variables the odds ratios for respiratory illness in boys and girls were 1.28 and 1.21. The observed excess risk was low and it cannot be ruled out that residual confounding from the controlled and other risk factors which were not controlled contributed to explaining the observed association. The wide confidence limits of the relative risk were a necessary consequence of a small total number: 54, of observed cases of respiratory illnesses.

In the course of the study we also analysed some domestic factors which might have had an effect on the incidence of the disease (24–26). As likely as it may seem that some of these factors influenced the rate of respiratory diseases in children, there was a significant difference between the control families only in respect to density of habitation, a measure of the socioeconomic status. Although some investigators have reported that home crowding significantly affected respiratory health (27, 28), our results are not consistent with these findings.

It is interesting to note a slight positive relationship between the level of parental education and the incidence/detection of respiratory illness in their children (r=0.18). However, these children had higher values of lung function tests. A possible explanation may be the differences in the interpretation of the questionnaire by the respondent and persistent differences in illness or reported rates associated with educational and cultural factors.

Children from homes with gas stoves had slightly lower mean FEV_1 values. Numerous studies have reported an increase in the frequency of respiratory symptoms in children living in houses with gas cooking appliances (25, 26, 29) but there is little evidence that damage to lung function comes from fumes generated during gas cooking (30). The documented variation in particulate and nitrogen dioxide concentrations among homes with an equal number of smokers or the same type of stove implies that the exposure variables used in these analyses are subject to substantial measurement errors (31).

The strong risk factor for respiratory illness among these children was parental smoking (32). Children of smokers had a 48% higher symptom rate than children of non-smokers. An increase in mean FEV_1 in children of smokers was the finding consistent with that of some other investigators (33). In the examined school children there was no significant association between FEV_1 values and the respiratory illness rate. The data on children living near the fertilizer plant indicated a small decrease in FEV_1 values in comparison with the mean FEV_1 values of children from the more distant school.

Results of this study suggest that the illness effect may be transient and effects on ventilatory function appear to be small. The explanation for these findings is that sample sizes were rather small. Another explanation could be that the exposure variables used did not adequately represent exposure to emissions from the fertilizer plant or that exposure may simply have been too low to cause detectable health effects. The differences in air pollutant concentrations between the exposed and control areas were lower than expected partly because of reduced fertilizer production and improved protective measures in the plant in the investigated period and partly because of the effects of other sources of pollution.

A long-term follow-up including refined measurement of personal exposure will be required for better understanding of the health significance of indoor and outdoor pollutants originating in the fertilizer industry.

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Sažetak

BOLESTI DIŠNOG SUSTAVA U ŠKOLSKE DJECE U BLIZINI TVORNICE MINERALNOG GNOJIVA

Šestomjesečnim praćenjem tijekom 1990/1991. godine ispitan je utjecaj kemijskih onečišćenja iz tvornice mineralnih gnojiva na akutne bolesti dišnog sustava i ventilacijsku funkciju pluća školske djece. Ispitana su 164 učenika drugih razreda dviju osnovnih škola smještenih 1–3 km od tvornice te 59 učenika škole u neindustrijskom području udaljene 22 km. Ventilacijska funkcija pluća određena je iz krivulje protok–volumen (Vicatest-5, Mijnhardt), a akutne respiracijske infekcije bilježene su tijekom čitavog razdoblja s pomoću upitnika upućenih roditeljima. Prikupljeni su i podaci o pušenju i obrazovanju roditelja kao i o uvjetima stanovanja. Istodobno su mjerene koncentracije amonijaka, plinovitih fluorida i dušik(IV)oksida u vanjskoj i unutrašnjoj atmosferi škola koje pohađaju djeca. Sve vrijednosti onečišćenja zraka ispod su preporučenih vrijednosti osim koncentracije amonijaka u jednoj od škola bližih tvornici. Učestalost respiracijskih simptoma nije se statistički značajno razlikovala u obje skupine (25:22%). Također nisu nađene statistički značajno niže srednje vrijednosti pokazatelja plućne funkcije u djece industrijskog područja.

Statističkom regresijskom analizom nađena je blaga povezanost bolesti dišnog sustava s obrazovanjem i pušenjem roditelja. U objašnjenju varijance forsiranog ekspiracijskog volumena (FEV_1) uz visinu i spol kao statistički značajne varijable (55%), sudjeluje i udaljenost škole od tvornice s neznačajnih 0.4%. Rezultati ne potvrđuju pretpostavku da mjerena onečišćenja zraka potekla iz tvornice mineralnih gnojiva uzrokuju bolest dišnih putova u školske djece. To, međutim, ne isključuje mogućnost da su neka djeca osjetljivija na navedene koncentracije ili da veće koncentracije štetno djeluju.

Ključne riječi:
onečišćenje zraka, testovi plućnih funkcija, tvornica mineralnih gnojiva

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