

Original articles

Symptoms of bronchial hyperreactivity and asthma in relation to environmental factors

S ANDRAE,* O AXELSON,† B BJÖRKSTÉN,‡ M FREDRIKSSON,† AND N-I M KJELLMAN‡

*Primary Health Care, Norrköping, Departments of ‡Pediatrics and †Occupational Medicine, Faculty of Health Sciences, University Hospital, Linköping, Sweden

SUMMARY A questionnaire study regarding airway morbidity in children and environmental factors was performed in April 1985. The parents of 5301 children, aged 6 months to 16 years, from different rural areas in mid Sweden were sent a validated questionnaire and 4990 (94%) responded. The cumulative prevalence of bronchial hyperreactivity was 9.7% and of allergic asthma 5.2%. Children living near a paper pulp plant more often had symptoms suggesting bronchial hyperreactivity (124 (13.0%), relative risk 1.3) and allergic asthma (68 (7.1%), relative risk 1.3). In children living in a damp house problem bronchial hyperreactivity was found in 76 (19.0%) (relative risk 1.9) and allergic asthma in 35 (8.7%) of the children (relative risk 1.9). Children living in a damp house with parents who smoked had the highest figures: bronchial hyperreactivity was found in 44 (23.5%) (relative risk 2.8) and allergic asthma in 22 (11.6%) (relative risk 2.5). The results indicate that various moderate environmental pollutants may act synergistically to increase bronchial hyperreactivity and allergy especially in children with a family history of allergy.

Several studies in recent years have indicated that the occurrence of asthma and allergic disorders may be increasing in industrialised countries.¹⁻⁴ The reasons for this are not fully understood, but various environmental pollutants may play a part. For example, exposure of children to tobacco smoke is widespread and has been shown to give increased bronchial hyperreactivity,⁵ an increased number of respiratory tract infections,⁶ wheezy bronchitis,⁷ increased prevalence of atopic disease,⁸ and increased serum IgE concentrations.⁹ Other air pollutants, which may affect the airways in children, include sulphur dioxide, which irritates mucosal membranes¹⁰ and may also facilitate production of IgE in laboratory animals.¹¹

The air indoors may become polluted because of evaporation of chemicals from plastic materials in carpets, furniture, and household equipment. In Scandinavia most houses built after the energy crisis in 1973 have been insulated extremely well in order to minimise heating costs. There is often less than 0.5 air exchanges per hour, which sometimes leads to increased dampness indoors with favourable conditions for mite and mould growth.

The aim of this study was to estimate the

importance of some environmental factors in the development of symptoms reflecting bronchial hyperreactivity and allergic conditions of the respiratory tract. (In the same study we also evaluated the incidence of respiratory tract infections.)

Subjects and methods

STUDY AREA

The population was comprised of children living in seven rural areas as defined by the 'zip' code and situated to the north and west of the city of Norrköping (fig 1). In area 4 there was a pulp and paper plant, but in the other areas there were no

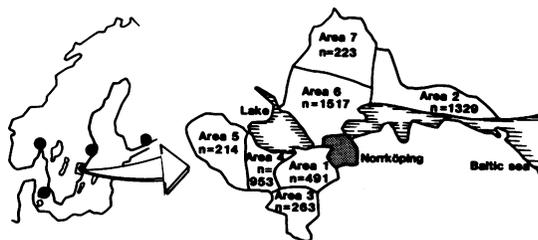


Fig 1 Map of Sweden and areas included in the study.

polluting industries. Pollution, from remote areas and the European continent in the form of solid particles that could directly influence the respiratory morbidity, has occurred occasionally, but was essentially similar in all the areas. (K Persson, head of the Meteorologic Department of the Swedish Meteorologic and Hydrologic Institute. Personal communication.)

For the purpose of studying the possible effects of general air pollution from industry, the children in areas 2 and 4 were selected for a detailed analysis. Area 2 was the area furthest away from area 4 and the city of Norrköping, and it was therefore least likely to be influenced by regional pollution. It was situated in a forested region about 150 m above sea level.

Area 4 with the combined paper pulp and paper making plant was situated in an open, flat country at about 5 m above sea level and was traversed by a river, which remained unfrozen during winter because of the process water from the factory. The warming up of the water resulted in some fog in the immediate vicinity of the river during part of the year. Apart from this the differences in climate between the areas were minor. The annual mean temperature was 0.3°C lower in area 2 than in area 4. The rainfall was 570 mm v 540 mm per year in the respective areas.

The pulp and paper plant operated continuously and processed 350 000 tons each year. The daily discharge of pollutants into the surrounding atmosphere was composed of roughly 0.1–1 tons of solids, 0.5 ton of sulphur dioxide, and 0.08 ton of hydrogen sulphide. Mercaptans were always present, causing the typical 'paper pulp plant smell' in the area, but the concentrations were extremely low. In addition, some chloride could have been released in the plant area, but this would have occurred only occasionally and in small quantities. Chlorinated organic material was likely to escape from the process, but no details were known in this respect. The discharge as measured in 1976 was even then below the Swedish health standards, that is, 0.012 ppm for sulphur dioxide and 0.003 ppm for solid particles as mean values for the six winter months.¹² Since 1976 the discharge from the plant has continuously decreased and is now only 5% of the level at that time. At the time of the study, however, there were periods with considerably higher concentrations of sulphur dioxide and the other discharges that lasted for a few hours. These periods occurred at least once every month.

QUESTIONNAIRE

A questionnaire was mailed in April 1985 to the parents of all 5301 children aged 6 months to 16

years who were living in the seven areas. Reminders were mailed after three and six weeks. By this procedure data were obtained from 4990 children (a response rate of 94%).

The questionnaire included 43 questions concerning various environmental factors, socioeconomic data, incidence of respiratory tract infections, symptoms of bronchial hyperactivity, and allergic disease. The environmental factors included in the questionnaire are summarised in table 1. For stratification in the statistical analyses the type of dwelling was used as a crude indicator of socioeconomic standard. The outcome variables are presented in table 2.

VALIDATION OF THE QUESTIONNAIRE

To validate the questionnaire 100 children were randomly selected from the original sample before the start of the study. Out of these, 95 responded to the questionnaire, and they were offered a physical

Table 1 *Environmental exposure factors*

Residential area
Type of dwelling (one family house or apartment)
Type of house (construction, building material, wall to wall carpets)
Type of heating
Signs indicating damage due to dampness in the house
Furred pets in the house at the time of the study and previously
Parental smoking at the time of the study and previously
Type of infant feeding during the first six months of life
Type of daily care for preschool children

Table 2 *Questions asked regarding hyperreactivity and allergy. (Frequency of items was based on the answers to these questions)*

1 Prolonged cough	Does your child usually cough for more than two weeks during an ordinary common cold?
2 Exercise-induced cough	Does your child often cough when exercising (running, playing) or otherwise getting short of breath?
3 'Breathing problem'	Has your child ever had a 'breathing problem' with heavy breathing and wheezing?
4 Allergic asthma	As for 3. Does this occur when in contact with deciduous trees, grass, flowers, or furred animals?
5 Allergic rhinitis	Has your child ever had attacks of sneezing, nasal congestion and/or an itching nose without having a cold? Does this occur when in contact with deciduous trees, grass, flowers, or furred animals?
6 Damage due to dampness	Does your dwelling have any damage caused by dampness?

Figures for items 3, 4, and 5 give the cumulative prevalence, while 1, 2, and 6 give the prevalence.

examination including a skin prick test and blood sampling. Five of the 95 responders could not be reached a second time; five declined to participate because of fear of test procedures and four had recently been to hospital for confirmed allergic disease and therefore declined.

The remaining 81 children with their parents were interviewed by a paediatrician (SA) and the answers were entered in a second questionnaire, which was identical to the one that had been mailed to the parents. These answers were then compared with the ones given by the subjects in the initial questionnaire.

The skin prick tests were performed with biologically standardised extracts of birch, timothy, and mugwort pollen, house dust mites, cat, horse, and dog epithelium, *Cladosporium* and *Alternaria* at a concentration of 100 000 biological units/ml (Pharmacia). Histamine chloride 10 mg/ml was used as a positive control.

Venous blood samples were obtained for analysis of total concentrations of serum IgE and concentrations of specific antibodies. The tests were done using Phadebas IgE PRIST and Phadebas RAST (Pharmacia) as recommended by the manufacturer.

A representative sample of 34 houses were visited by health inspectors to evaluate 'damage due to dampness.'

STATISTICAL METHODS

The statistical analyses of the data were based on the Mantel-Haenszel procedure for the calculation of χ^2 values and for the estimation of the overall rate ratios.^{13 14} Stratification was found necessary in various respects to account for possible confounding and modification of effect as further indicated in the tables of the result section.

The validation study was approved by the Human Research Ethics Committee of the University of Linköping.

Results

VALIDATION OF THE QUESTIONNAIRE

A 95% concordance was obtained for the questions about bronchial hyperreactivity and asthma between the answers in the interviews and the questionnaires. The questions about the construction material of their houses were, however, difficult to answer for most parents and were therefore excluded from the final analysis of the data. For all the other questions used in the questionnaire the specificity was 70% and the sensitivity 90%.

Thorough analysis of the representative selection of 34 houses confirmed that when parents claimed that there was a damage due to dampness in the

house, experienced health inspectors agreed. Visible mould growth or a specific smell, or both, were noted by the inspectors in 14 out of 23 'damp' houses v only three out of 11 houses where no dampness was suspected. In the nine houses in which dampness was claimed to occur and no confirmation could be obtained, there were indications of dampness in the past—for example, dry damp spots and also reports of an improvement of the drainage system.

Samples of dust and air from the houses were also obtained for the quantification of moulds, house dust mites, and green algae. The preliminary results indicated that at least in the 14 houses that had been examined in detail, damage due to dampness really meant internal mould sources. House dust mites were found only in low quantities in four houses, all of which had dampness spots. (S Andrae, O Axelson, B Björkstén. Allergens in modern insulated houses. Paper in preparation.)

HEALTH EFFECTS

The morbidity was influenced mainly by (a) residential area, (b) type of dwelling, (c) damage due to dampness in the house, and (d) parental smoking.

No effects on the morbidity were noted for children with current exposure in the house to furred pets (2327, 47%), cage birds (934, 20%), or aquarium fish (1098, 23%). For the final evaluation of each one of the first four factors mutual stratification was undertaken for control of the others.

(a) Residential area

The areas differed with regard to type of dwelling, with 209 (22%) in area 4 and 125 (9%) in area 2 living in apartments. There were no major differences between the two areas concerning parental smoking: 444 (46%) v 586 (44%); history of breast feeding for at least six months: 271 (29%) v 388 (30%); dampness damage in the house: 89 (9%) v 108 (8%), and living in a family with only one adult: 51 v 70 (5% in both areas).

Area 4, which had the pulp and paper plant, had the highest prevalence of allergic rhinitis, allergic asthma, and prolonged coughing during upper respiratory tract infections (tables 3 and 4). There was a difference for all types of allergic asthma, but the difference was most noticeable for asthma during the birch pollen season, presumably indicating birch pollen induced asthma. For asthma and coughing the differences between the areas were most noticeable for children, 8 years and older, area 4 having the higher rates.

(b) Type of dwelling

Children living in one-family houses—which indirectly reflected better social conditions in

general—tended to have allergic symptoms more often than children living in apartments, although this was not significant. Children living in apartments had parents who smoked in 440 (55%) instances ν 1689 (41%) instances for those living in one-family houses ($p < 0.001$).

(c) *Damage due to dampness in the house*

Living in houses with damage due to dampness

independent of family smoking habits was associated with a significantly increased occurrence of prolonged coughing after respiratory tract infections: 76 (19.0%) ν 404 (9.1%); exercise-induced coughing: 36 (8.9%) ν 253 (5.5%); allergic rhinitis: 38 (9.4%) ν 308 (6.7%); and allergic asthma: 35 (8.7%) ν 228 (5.0%). These environmental factors caused most noticeable effects in children having a family history of asthma with 23 (5.9%) occurrences

Table 3 *Crude occurrence of symptoms of bronchial hyperreactivity and allergic disease in the different areas. (Figures are percentages)*

Area	1	2	3	4	5	6	7	All areas
No of children	491	1329	263	953	214	1517	223	4990
Coughing >2 weeks during upper respiratory tract infections	8.5	8.2	8.8	13.0	9.5	9.6	9.6	9.7
Exercise induced cough	5.1	5.9	7.3	6.3	6.5	5.7	5.0	5.9
Allergic asthma (total)	5.0	5.5	3.4	7.1	5.6	4.3	5.8	5.3
Birch pollen induced asthma	2.6	2.5	1.0	4.4	3.3	2.5	1.4	2.8
Allergic rhinitis	7.9	6.7	4.9	8.8	8.4	6.6	2.7	7.0

The bold figures signify the highest value for each item.

Table 4 *Mantel-Haenszel risk ratios for living in area 4 ν area 2 at different ages; in total 12 strata. (Underlying stratification for parental smoking, damage due to dampness at home, and type of dwelling not shown)*

	Age interval			<i>p</i> Value for 6 months to 16 years (95% confidence interval)
	6 months–7 years	8–16 years	6 months–16 years	
Coughing >2 weeks during upper respiratory tract infection	1.3	1.8	1.5	<0.05 (1.4 to 1.6)
Exercise induced cough	1.0	1.0	1.0	NS
Allergic asthma (total)	1.0	1.5	1.3	NS
Birch pollen induced asthma	1.2	2.0	1.8	<0.001 (1.6 to 2.3)
Allergic rhinitis	1.3	1.3	1.3	<0.05 (1.1 to 1.6)

Table 5 *Mantel-Haenszel risk ratios showing combined effect of parental smoking and living in houses with damage due to dampness on bronchial hyperreactivity and allergic disease. (Underlying stratification for residential area and type of dwelling not shown)*

	Parents not smoking		Parents smoking	
	Damage due to dampness not present (n=2581)	Damage due to dampness present (n=212)	Damage due to dampness not present (n=1958)	Damage due to dampness present (n=187)
Coughing >2 weeks during upper respiratory tract infection	1.0	1.9* (1.3 to 2.9)	1.3* (1.1 to 1.6)	2.8† (2.0 to 4.1)
Exercise induced cough	1.0	1.0	1.2	2.2† (1.4 to 3.5)
Allergic asthma	1.0	1.3	0.9	2.5† (1.5 to 3.7)
Birch pollen induced asthma	1.0	1.7	0.9	2.9† (1.5 to 5.5)
Allergic rhinitis	1.0	1.1	1.0	1.8* (1.1 to 2.8)

Level of significance ν non-smoking and no dampness: * $p < 0.05$; † $p < 0.001$. 95% Confidence intervals in parentheses.

of allergic asthma in children in houses undamaged by dampness ($n=389$) v 11 (2.4%) occurrences in children in houses damaged by dampness ($n=54$) ($p<0.001$). In children with no family history of asthma the numbers were 78 (1.9%) ($n=4108$) v 8 (2.4%) ($n=336$); this was not significant. The number of occurrences of allergic asthma were significant when children with and without a family history of asthma and not living in houses damaged by dampness were compared ($p<0.001$) and when children with and without a family history of asthma but who were living in houses damaged by dampness were compared ($p<0.001$). Even when asthma induced by house dust was excluded from the analysis the relation between environmental factors and allergic disorders was significant.

Type of house construction—for example, presence of a basement, did not influence the prevalence of any of the clinical symptoms in the children.

(d) Parental smoking

Children with parents who smoked had exercise induced cough more often than the children of non-smokers: 150 (7.0%) v 143 (5.1%) ($p<0.01$). For

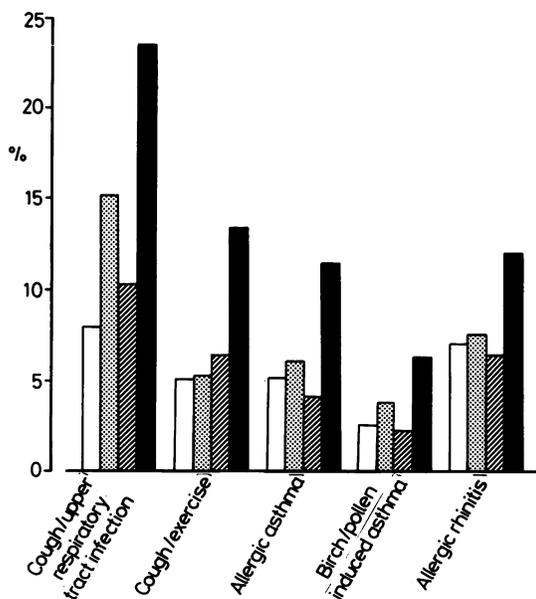


Fig 2 Occurrence (%) of symptoms suggesting bronchial hyperreactivity and allergic disease in relation to parental smoking and damage due to dampness at home in 4938 children. No parental smoking and no damage due to dampness □ ($n=2581$); no parental smoking and damage due to dampness ▨ ($n=212$); parental smoking and no damage due to dampness ▤ ($n=1948$); and parental smoking and damage due to dampness ■ ($n=187$).

children with parents who smoked, living in houses with damage by dampness, there was a noticeable increase in exercise induced cough, allergic rhinitis, and allergic asthma, particularly when compared with children not exposed to any of these factors but also in comparison with children exposed to only one of them (table 5 and fig 2).

Discussion

Children living in area 4—that is, in the neighbourhood of the pulp and paper mill—had symptoms of bronchial hyperreactivity and allergic diseases more often than children of the same age living in an area with little local pollution. Possible explanations for the findings include socioeconomic differences, overreporting in the area, climatic differences, and an irritating effect of industrial pollutants.

These differences remained significant even when type of dwelling, which was used as a crude measurement of socioeconomic differences, was accounted for by stratification. The fact that there was occasionally a pronounced smell of mercaptans in area 4 might have caused concern over discharge of air pollutants and a subsequent overreporting of health effects—that is, with regard to even minor symptoms. On the other hand, the pulp plant is the sole major employer in the area and thus represents employment and prosperity for the local population, which may even have reduced the tendency to report symptoms. In the validation study, however, no signs of overreporting or underreporting were found when this area was studied in relation to other areas.

The differences between the two areas were greater for schoolchildren than for preschool children. If the recorded differences had merely been the result of overreporting no clear age difference would have been expected. It is even reasonable to assume that overreporting would have been more pronounced for the younger children as they spend more time at home and because the social consequences of disease in a young child are usually greater for the family than if the child is older.

Climatic differences between the areas could have been considered as an additional factor influencing the results but according to the Swedish Meteorologic and Hydrologic Institute in Norrköping, these differences are minor, and the areas have in fact an almost identical climate. (K Persson, head of the Meteorologic Department of the Swedish Meteorologic and Hydrologic Institute. Personal communication.)

It seems reasonable to consider the symptoms as a possible effect of industrial pollution as there is no clear indication of other factors explaining the

differences. In this context the occasional occurrence of high concentrations of sulphur dioxide are particularly interesting as it is well known that sulphur dioxide in high concentrations causes irritation of human mucous membranes.¹⁰ Moreover, in animal experiments sulphur dioxide has been shown to enhance IgE antibody formation.¹¹ Other undefined pollutants, however, may also have contributed.

The findings that children living in homes damaged by dampness more often had signs of bronchial hyperreactivity and allergic disease cannot fully be explained. Localised damage caused by dampness in a house often leads to mould formation. The amount of this internal mould growth as well as the species concerned may vary. Increased humidity may also be associated with increased number of house dust mites.

Moulds are known to cause allergic reactions but they may possibly, in addition, have other effects on the airways as indicated by a recent report in which there was a correlation between upper respiratory tract symptoms in adults and exposure to aspergillus moulds in the homes.¹⁵

The effect of living in a damp house as related to the occurrence of allergic asthma was particularly obvious for children with a family history of atopic disease. This was true not only for 'dust' allergy, but also for allergy to birch pollen, which has a well defined season, indicating an unspecific environmental effect on the airways in children. Consistent with our findings are those reported of an increased prevalence of symptoms, presumably induced by mould exposure, in smokers compared with non-smokers in adults.¹⁵

Children living in area 4 had a higher prevalence of symptoms of bronchial hyperreactivity and allergy than children living in other areas. A possible confounding factor concerning the effect of residential area is the fact that the school building for children, age 7–11 years, in area 4 had a serious mould problem. This cannot, however, explain the higher than expected morbidity in preschool children.

In conclusion, this questionnaire survey indicates that exposure to tobacco smoke in the home, housing conditions, and even moderate environmental pollution from a pulp and paper factory may all affect the respiratory tract of children. This in

turn may lead to signs of bronchial hyperreactivity and respiratory allergy in some children. The effects of these environmental factors appear to be synergistic.

This study was supported by grants from the Konsul Th Berg Foundation, the Annual Campaign of First of May Flower, the Åhlén Foundation, and the County Council of Östergötland.

References

- Morrison Smith J, Harding LK, Cumming G. The changing prevalence of asthma in school children. *Clin Allergy* 1971;1:57–61.
- Taylor B, Wadsworth J, Wadsworth M, Peckham C. Changes in the reported prevalence of childhood eczema since the 1939–45 war. *Lancet* 1984;i:1255–7.
- Kjellman B, Pettersson R, Hensjö B. Allergy among school children in a Swedish county. *Allergy* 1982;37(suppl 1):5–6.
- Hattevig G, Kjellman B, Björkstén B, Johansson SGO. The prevalence of allergy and IgE antibodies to inhalant allergens in Swedish school children. *Acta Paediatr Scand* 1987;76:349–55.
- Ware JH, Dockery DW, Spiro FE, Ferris Jr BG. Passive smoking, gas cooking and respiratory health of children living in six cities. *Am Rev Respir Dis* 1984;129:366–74.
- Harlap S, Davies DM. Infant admissions to hospital and maternal smoking. *Lancet* 1974;i:529–32.
- Cogswell JJ, Mitchell EB, Alexander J. Parental smoking, breast feeding and respiratory infection in development of allergic disease. *Arch Dis Child* 1987;62:338–44.
- Gortmaker SL, Klein Walder D, Jacobs FH, Ruch-Ross H. Parental smoking and the risk of childhood asthma. *Am J Public Health* 1982;72:574–9.
- Kjellman N-IM. Effect of parental smoking on IgE levels in children. *Lancet* 1981;i:993–4.
- Ware JH, Ferris Jr BG, Dockery DW, Spengler JD, Stram DO, Speizer FE. Effect of ambient sulfur oxides and suspended particles on respiratory health of preadolescent children. *Am Rev Respir Dis* 1986;133:834–42.
- Oscold JW, Gerschwinn LJ, Zee YC. Studies on the enhancement of allergic lung sensitization by inhalation of ozone and sulfuric acid aerosol. *J Environ Pathol Toxicol* 1980;3:221–34.
- Report on ambient sulfur oxides and suspended particles in Norrköping 1973–1981. Norrköping: Department of Environmental Health 1981 (in Swedish).
- Mantel N, Haenszel W. Statistical aspects of the analysis of data from retrospective studies of disease. *Journal of National Cancer Institute* 1959;32:719–48.
- Mantel N. Chi-square tests with one degree of freedom: extension of the Mantel–Haenszel procedure. *American Statistical Association Journal* 1963;690–700.
- Holmberg K. *Health effects due to mould exposure in dwellings*. Stockholm: Swedish Council of Building Research, Report 36, 1985 (in Swedish with an English summary).

Correspondence to Dr S Andrae, Department of Pediatrics, County Hospital, S–601 82 Norrköping, Sweden.

Accepted 15 December 1987