Indoor Air Pollution and its Effects on Health*

R. J. W. MELIA, C. du V. FLOREY, S. CHINN, B. D. GOLDSTEIN,[1] A. G. F. BROOKS,[2] H. H. JOHN,[3] D. CLARK,[4] I. B. CRAIGHEAD[3] and X. WEBSTER[3]
Department of Community Medicine, St. Thomas's Hospital Medical School, London, SE1 7EH

INTRODUCTION

IN THE past research into the effects on health from air pollution has concentrated on outdoor pollutants. In the U.K. attention was drawn to the problem of high levels of atmospheric smoke and sulphur dioxide (SO_2) by the rapid increases in mortality and morbidity rates which occurred during episodes of smog (Ministry of Health, 1954). Major disasters of this kind have not arisen from pollution inside the home and the indoor environment was thought to provide protection from pollution outside. SO_2 for example is absorbed by fabrics and soft furnishings so unless there is an indoor source the concentrations of SO_2 tend to be lower inside than out (Benarie et al., 1974; Biersteker et al., 1965).. However it is now realized that indoor sources of pollution can cause higher levels of certain pollutants such as oxides of nitrogen and carbon monoxide inside than outside the home (Goldstein et al., 1979; Wade et al., 1975). The levels of atmospheric smoke and SO_2 in the U.K. have been declining over several decades (Weatherley et al., 1976) and their effects on respiratory illness are no longer easily detected by epidemiological methods (Lawther et al., 1970; Lunn et al., 1970). It is therefore possible that effects from indoor pollution may become more apparent than in the past. Among the pollutants which could be associated with respiratory disease are those which arise from tobacco smoking, and the combustion of gas and oil (Table I). Coal fires may have been at one time a source of indoor pollution but changes in the type of fires and solid fuel have helped to reduce the levels of pollution from this source in the home. Pollution from other indoor sources are also potentially harmful to health (Table I). Asbestos used for thermal insulation and radon emitted from building material may be hazardous in the long term because of their carcinogenic properties. Carbon monoxide coming from the combustion of gas and present in tobacco smoke interferes with the transport of oxygen in the blood and may exacerbate the condition of cardiorespiratory patients. Formaldehyde released from building materials such as particle boards and foamed insulation can cause irritation to the eyes and respiratory tract. There is also a variety of other pollutants too numerous to mention here which are released from household goods such as sprays. Pollutants known to be harmful at work can also be present at home because the same materials are used for hobbies.

TABLE I
Summary of some indoor air pollutants, their sources and potential effects on health

Pollutant	Source	Potential effect on health
Asbestos	Building materials	Cancer
Carbon monoxide	Gas appliances Tobacco smoke	Hypoxia
Formaldehyde	Building materials	Irritation to eyes and respiratory tract
Nitrogen	Gas appliances Oil fires Tobacco smoke	Respiratory illness
Radon	Building materials	Cancer
Suspended particulates	Coal fires Tobacco smoke	Respiratory illness

Concern about the indoor environment is increasing as ventilation rates are being reduced to conserve energy and the levels of pollution may become higher than they were in the past. Guidelines for the control of certain pollutants have been proposed by bodies such as the World Health Organization. Recommendations have been made for the maximum levels above which people should not be exposed but there has been much criticism of these guidelines. Some of the guidelines have been based mainly on the results of animal experiments which are not necessarily applicable to man. Further information has come from studies of occupational health but the effects on health and levels of exposure may differ for the general population. There have been many epidemiological investigations into the ill effects of outdoor air pollution but these have been mainly concerned with pollutants such as suspended particulates and SO_2. At a workshop on indoor air pollution organized by WHO (1979) it was recognized that there was a need for research into the indoor environment and its effects on health. The

*Presented at the seminar "Health in the Home" organised by the Chartered Institution of Service Engineers and the Royal Society of Health on 7th May, 1980, at the Electricity Council Research Centre, Chester.

1. College of Medicine and Dentistry of New Jersey, Rutgers Medical School, University Heights, Piscataway, New Jersey 08854-USA. 2. MRC Toxicology Unit (Clinical Section), St. Bartholomew's Hospital Medical College, Charterhouse Square, London, EC1M 6BQ. 3. Cleveland Area Health Authority, Marton House, Borough Road, Middlesbrough, Cleveland, TS4 2EJ. 4. Middlesbrough Borough Council Environmental Health Department, Vancouver House, Central Mews, Quarry Street, Middlesbrough, Cleveland, TS1 1QS.

TABLE III
The Cleveland Respiratory Study
The frequency (%) of one or more respiratory conditions in boys and girls from homes where only electricity was used for cooking and from homes where only gas was used grouped according to the weekly average level of NO_2 in the children's bedrooms (ppb) (total number of children given in brackets).

	Electric cooking homes	Gas cooking homes: level of NO_2 (ppb)		
		4-19	20-39	40-169
Boys	40 (42)	43 (23)	58 (19)	69 (13)
Girls	47 (34)	44 (25)	60 (15)	75 (8)

samplers and questionnaires. Measurements of NO_2 were taken by two samplers placed for one week in the kitchen of each home and in a random 25 per cent of homes a third sampler was placed in the child's bedroom. Information on respiratory symptoms and diseases experienced by the child and on the characteristics of the home was collected in a questionnaire completed by the child's mother. Data were obtained for 66 per cent of the sample. The levels of NO_2 in the kitchens were considerably higher where gas was used for cooking (range 5-317 ppb; mean 112·2 ppb) than where electricity was used (range 6-188 ppb; mean 18 ppb). Levels in the bedroom were also higher in homes with a gas cooker (range 4-169 ppb, mean 31 ppb) than in homes with an electric cooker (range 3-37 ppb, mean 14 ppb).

The relation between respiratory illness and type of fuel used for cooking was similar to that found in the National Study. The risk of having one or more respiratory conditions was higher in homes with a gas cooker than homes with an electric one ($p = \cdot 06$) independent of effects from age, sex, social class and smoking in the home. However no relation was found between the frequency of respiratory conditions and levels of NO_2 in the kitchen or between lung function and levels of NO_2 in the kitchen or bedroom. Only one finding indicated that levels of NO_2 might be related to respiratory illness. Within gas cooking homes the frequency of respiratory conditions was higher in homes with high levels of NO_2 in the bedroom than homes with low levels (Table III). After allowing for the effects of age, sex, social class and number of smokers in the home the relation between respiratory illness and levels of NO_2 in the bedrooms of homes with gas cookers was statistically significant at the 10 per cent level. No relation was found between respiratory illness in the parents and the type of fuels used for cooking in the home or levels of NO_2.

DISCUSSION

AN ASSOCIATION between gas cooking and respiratory illness has now been found in three different groups of children in the U.K. Although no association has been found in some studies from the U.S.A. (Lutz et al., 1974; United States Environmental Protection Agency, 1976) Speizer and colleagues (1979) have reported a relation in schoolchildren between use of gas for cooking and both a history of respiratory illness before the age of two and poor lung function. The suggestion that indoor pollution is the cause of the association needs to be investigated further for the results from the Cleveland Respiratory study show some inconsistencies. An association was found between respiratory illness and levels of NO_2 in the bedroom but not the kitchen. Possibly the levels in the kitchen did not provide an appropriate measure of levels to which the children were being exposed in their homes or peak levels of NO_2 may relate more closely to the frequency of respiratory illness than average levels. Alternatively another environmental agent or social conditions associated with the use of gas may be the cause. We are currently studying the possibility that gas cooking may be associated with high humidity in the home which may lead to condensation, increased ventilation and low temperatures. The fact that no relation was found between respiratory illness in the parents and gas cooking or levels of NO_2 is not surprising since children tend to suffer from more illness and may be more susceptible to the effects of indoor pollution than their parents. Indoor pollution from tobacco smoking by members of the family did not appear to be related to respiratory illness in the children from Middlesbrough. This may indicate that the effect from gas cooking is more important than that from smoking on primary schoolchildren. In a study of children followed-up from birth to age five (Colley et al., 1974) an association between parents' smoking habits and the incidence of bronchitis and pneumonia was found only during the first year of life and disappeared as the children grew older. The effect of gas cooking was not investigated in this study.

CONCLUSIONS

THERE IS a variety of pollutants in the home which are potentially harmful to health. If ventilation rates are reduced to conserve energy the risk to health may increase as the levels of pollution are raised. Changes in the indoor environment and its effects on health should be carefully monitored. Some pollutants are difficult to study because their effects on health will take some time to develop or because suitable monitoring instruments are not available for use in surveys of health. In preliminary investigations the effects of pollution may be studied indirectly using their sources to identify groups of the population who may be exposed to different levels of pollution. Pollution arising from gas cooking has been studied in this way. If pollution from gas combustion is indeed harmful to health it might be simply dispelled by improving ventilation in the kitchen. This could be done by opening the windows while cooking or an aid to ventilation such as an air vent, cooker hood or even a flue could be employed.

ACKNOWLEDGEMENTS

OUR INVESTIGATIONS into gas cooking were funded by grants from the Department of Health and Social Security. We are grateful to Professor W. W. Holland who initiated and directed the National Study of Air Pollution and who has encouraged us in our work.

REFERENCES

APLING, A. J., STEVENSON, K. J., GOLDSTEIN, B. D., MELIA, R. J. W. and ATKINS, D. H. F. Air Pollution in homes. 2: Validation of diffusion tube measurements of nitrogen dioxide. *Warren Spring Laboratory, Stevenage,* Publ. No. LR 311 (AP), 1979.

BECKLAKE, M. R., GOLDMAN, H. I. BOSMAN, A. R. and Freed, C. C. The long-term effects of exposure to nitrous fumes. *American Review of Tuberculosis and Pulmonary Disease,* **76,** 398-409, 1957.

BENAIRE, M., MENARD, T. and NONAT, A. Comparaison des concentrations de 24h. de SO_2 et des fumées noires à l'extérieur et a l'intérieur d'un bâtiment en fonction de son occupation. *Atmospheric Environment,* **8,** 149-157, 1974.

BIERSTEKER, K., DE GRAAF, H. and NASS, CH A. G. Indoor air pollution in Rotterdam homes. *International Journal of Air and Water Pollution,* **9,** 343-350, 1965.

effects on health of some pollutants are difficult to study epidemiologically because we do not have suitable measuring instruments for use in large surveys. However preliminary investigations may be conducted by using sources of pollution to identify groups of the population exposed to different levels of pollution. Both tobacco smoking (Colley et al., 1974; Leeder et al., 1976) and fuels used for cooking in the home (Melia et al., 1977; Melia et al., 1979) have been employed in this way. The main disadvantage of this method of research is that several types of pollutants may arise from one source so further work is required to identify which of them may be causing ill-effects on health. Other pollutants cannot be studied by their source because the population cannot easily be divided into exposed and non-exposed groups.

The results of investigations into the association between respiratory illness in primary schoolchildren and use of gas for cooking in the home illustrate the type of epidemiological studies which may be conducted.

INVESTIGATIONS INTO THE EFFECTS OF GAS COOKING

The National Study

An association between respiratory illness and use of gas for cooking in the home was first observed in a National Study of Air Pollution. Six to 11 year olds from selected primary schools in a random sample of 22 English and six Scottish areas were studied annually from 1973 to 1977. Information on the presence of cough, wheeze, colds going to the chest and history of asthma and bronchitis was collected in a questionnaire completed by the mothers. Questions were also asked about socio-economic characteristics of the home such as the father's social class, and indoor sources of pollution such as the types of fuel used for cooking and heating, and in 1977 only, the number of smokers in the home. As new children entered the study each year when they reached the age of six and older children left when they moved on to secondary school the population examined in 1977 differed from that examined in 1973. The association between gas cooking and respiratory illness was studied in both groups of children to see if it was repeatable in two different populations (Melia et al., 1977; Melia et al., 1979). The results from both years were compared by calculating the risk of having one or more respiratory conditions in homes where only gas was used for cooking relative to the risk in homes where only electricity was used (Table II). In each group of children the risk was greater in homes with a gas cooker than homes with an electric cooker. After allowing for differences in age and social class between gas and electric cooking homes this relative risk in boys was found to be similar in both years but the relative risk in girls was greater in 1973 than 1977. In further analyses in 1977 the association was observed to be independent of the effects of age, social class, the number of smokers in the home and latitude of the areas but it was only statistically significant in urban areas (for boys $p < \cdot 005$; for girls $p \simeq \cdot 08$).

TABLE II
The National Study

The risk of having one or more respiratory conditions in primary schoolchildren from homes where gas was used for cooking relative to the risk in children from homes where electricity was used after allowing for differences in age and social class given by sex and year of examination.

	Year of examination	
	1973	1977
Boys	1·29 ($p < \cdot 05$)	1·25 ($p < \cdot 05$)
Girls	1·40 ($p < \cdot 001$)	1·19 ($p \simeq \cdot 07$)

As the gas cooker is an unflued appliance we suggested that indoor air pollution might be the cause of the association. Among the many pollutants which arise in the emissions of gas combustion NO_2 was suspect. NO_2 has been found to cause increased susceptibility to respiratory infection in animals exposed to levels of about 500 ppb for three months. (Ehrlich and Henry, 1968) and pulmonary oedema in man exposed to much higher levels in industrial and agricultural accidents (Becklake et al., 1957; Grayson, 1956). Furthermore, weekly average concentrations of NO_2 in kitchens with a gas cooker have been shown to be above the maximum annual mean level of 50 ppb recommended by the United States Environmental Protection Agency (Wade et al., 1975). At the time of writing our first report (Melia et al., 1977) a small personal sampler for NO_2 became available which was highly suitable for use in surveys (Palmes et al., 1976). Before we embarked on a large study of the relation between NO_2 and respiratory illness we first tested the reliability of the sampler.

SAMPLER EXPERIMENT

The sampler consists of an acrylic tube about 3 in. long with an internal diameter of $\frac{3}{8}$ in. which contains an absorbant specific to NO_2. The sampler depends on the molecular diffusion for the collection of gas so no pump or electrical supply is required. The total amount of NO_2 which has been absorbed over a measured period of time is determined by spectrophotometry to obtain an average measure of the concentration in the atmosphere. In a designed experiment conducted in two gas and two electric kitchens we found that the reliability of the sampler was highly satisfactory, the measurement error being 1·2 ppb (Melia et al., 1978). When the measurement from the sampler was compared with the measurement taken by the chemiluminescent method it was concluded that the accuracy of the sampler was better than ±10 per cent when used in domestic kitchens (Apling et al., 1979).

THE CLEVELAND RESPIRATORY STUDY

The main aim of the study was to investigate whether lung function was related to levels of NO_2 in the home (Florey et al., 1979). We chose to study young primary schoolchildren coming mainly from the manual social classes and living in an urban area of northern England with a high risk of developing respiratory disease. 808 six to seven year olds who both lived and attended school within a defined area of local authority housing in Middlesbrough were included in the study in February 1978. Outdoor air pollution might have interfered with our results but levels of smoke and SO_2 which were already being measured at two sites in the area were low (annual means $\leq 30\ \mu g/m^3$). Outdoor levels of NO_2 which were measured at 75 sites set up in the study area by staff of the Middlesbrough Borough Council for one week in February were found to be low and similar across the area (range: 14 to 24 ppb). Height, weight and lung function were measured on each child at school by trained fieldworkers from St. Thomas's Hospital. Lung function was measured using the McDermott Dry Spirometer supplied by the MRC Toxicology Unit. School nurses from the Cleveland Area Health Authority were responsible for the distribution of NO_2

COLLEY, J. R. T., HOLLAND, W. W. and CORKHILL, R. T. Influence of passive smoking and parental phlegm on pneumonia and bronchitis in early childhood. *Lancet*, **2**, 1031-1034, 1974.

EHRLICH, R. and HENRY, M. C. Chronic toxicity of nitrogen dioxide. I. Effects on resistance to bacterial pneumonia. *Archives of Environmental Health*, **17**, 860-865, 1968.

FLOREY, C. DU V., MELIA, R. J. W., CHINN, S., GOLDSTEIN, B. D., BROOKS, A. G. F., JOHN, H. H., CRAIGHEAD, I.B. and WEBSTER, X. The relation between respiratory illness in primary schoolchildren and the use of gas for cooking. III. Nitrogen dioxide, respiratory illness and lung function. *International Journal of Epidemiology*, **8**, 347-353, 1979.

GOLDSTEIN, B. D., MELIA, R. J. W., CHINN, S., FLOREY, C. DU V., CLARK, D. and JOHN, H. H. The relation between respiratory illness in primary schoolchildren and the use of gas for cooking. II. Factors affecting nitrogen dioxide levels in the home. *International Journal of Epidemiology*, **8**, 339-345, 1979.

GRAYSON, R. R. Silage gas poisoning: nitrogen dioxide pneumonia, new disease in agricultural workers. *Annals of Internal Medicine*, **45**, 393-408, 1956.

LAWTHER, P. J., WALLER, R. E. and HENDERSON, M. Air pollution and exacerbations of bronchitis. *Thorax*, **25**, 525-539, 1970.

LEEDER, S. R., CORKHILL, R., IRWIG, L. M., HOLLAND, W. W. and COLLEY, J. R. T. Influence of family factors on the incidence of lower respiratory illness during the first year of life. *British Journal of Preventive and Social Medicine*, **30**, 203-212, 1976.

LUNN, J. E., KNOWELDEN, J. and ROE, J. W. Patterns of respiratory illness in Sheffield junior schoolchildren. *British Journal of Preventive and Social Medicine*, **24**, 223-228, 1970.

LUTZ, G. A., MITCHELL, R. I., COTE, R. W. and KELLER, M. D. Indoor Epidemiology Study. Battelle, Columbus Laboratories, catalog No. M50677, 1974.

MELIA, R. J. W., FLOREY, C. DU V., ALTMAN, D. G. and SWAN, A. V. Association between gas cooking and respiratory disease in children. *British Medical Journal*, **2**, 149-152, 1977.

MELIA, R. J. W., FLOREY, C. DU V. and CHINN, S. The relation between respiratory illness in primary school children and the use of gas for cooking. I. Results from a national study. *International Journal of Epidemiology*, **8**, 333-338, 1979.

MELIA, R. J. W., FLOREY, C. DU V., DARBY, S. C., PALMES, E. D. and GOLDSTEIN, B. D. Differences in NO_2 levels in kitchens with gas or electric cookers. *Atmospheric Environment*, **12**, 1379-1381, 1978.

MINISTRY OF HEALTH. Mortality and morbidity during the London fog of December 1952. *Report on public health and Medical Subjects* no. 95, HMSO, London, 1954.

PALMES, E. D., GUNNISON, A. F., DIMATTIO, J. and TOMCZYK, C. Personal sampler for nitrogen dioxide. *American Industrial Hygiene Association Journal*, **37**, 570-577, 1976.

SPEIZER, F. E., FERRIS, B., BISHOP, Y. M. M. and SPENGLER, J. Health effects of indoor NO_2 exposure. Preliminary results. Paper given at the American Chemical Society/Chemical Society of Japan Chemical Congress, Honolulu, 1979.

US ENVIRONMENTAL PROTECTION AGENCY. Scientific and Technical Data Base for Criteria and Hazardous Pollutants. 1975 ERC/RTP Review, EPA Publ. No. EPA — 600/1-76-023, pp.206-207, 1976.

WADE, W. A., COTE, W. A. and YOCOM, J. E. A study of indoor air quality. Journal of the Air Pollution Control Association. **25**, 933-939, 1975.

WEATHERLEY, M.-L., P. M., GOORIAH, B. D. and CHARNOCK, J. Fuel consumption, smoke and sulphur dioxide emissions and concentrations, and grit and dust deposition in the UK, up to 1973-74. LR 214(AP), Warren Spring Laboratory. Stevenage, 1976.

WORLD HEALTH ORGANIZATION. Health Aspects related to indoor air quality. Report on a WHO Working Group. World Health Organization. Copenhagen, 1979.

Annual Subscriptions, 1981

Members are reminded that annual subscriptions were due on 1st January 1981. The current rates are as follows.

	£		£
Fellow	17.00	Associate Member	9.00
Member	11.00	Affiliate	7.00

These rates have not been increased since January 1979, in spite of a general rate of inflation of about 34% since that date. The subscriptions have been held steady only by exercising the greatest economy in managing the affairs of the Society.

Prompt payment of subscriptions is helpful to the Society in planning future activities, and avoids the necessity for costly reminders (postage rates are expected to rise again in the near future).

Members who wish to pay by Banker's Order may obtain the necessary forms from the Secretary. This method of payment saves time and trouble, and ensures that payment will not be overlooked.

Members are reminded that tax relief may be claimed in respect of subscriptions paid to the Society.

North America

Subscription rates for Fellows and Members in North America are as follows:

Fellow	$50	Member	$35

As the Society is an educational body and a non-profit making organisation, members are usually able to claim that their dues are tax-deductible.