EUROPEAN CONCERTED ACTION

INDOOR AIR QUALITY & ITS IMPACT ON MAN

COST Project 613

Environment and Quality of Life

Report No. 3
Indoor Pollution by NO_2 in European Countries

Commission of the European Communities
Directorate General for Science, Research and Development
Joint Research Centre - Institute for the Environment

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prepared by
The Community-COST Concertation Committee
on behalf of the Community - COST Concertation Committee

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Published by the
COMMISSION OF THE EUROPEAN COMMUNITIES

Directorate-General
Information Market and Innovation

Batiment Jean Monnet
LUXEMBOURG

Cataloguing data can be found at the end of this publication.

Luxembourg: Office for Publications of the European Communities, 1989

Printed in Italy

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1. Introduction

In the framework of the concerted action "Indoor Air Quality and Its Impact on Man" (COST project 613) the Community - COST Concertation Committee (CCCC) has reviewed the status of indoor air quality with respect to NO_2. Emphasis is put on the specific situations in the various countries participating in the concerted action. However, for several countries no information has been brought to the attention of the CCCC. The scope of this review is to identify differences and common denominators with respect to various aspects of indoor pollution by NO_2 and to help to identify a European view of the issue.

2. Health Effects

The health effects of NO_2 have been reviewed and evaluated in a number of reports (Morrow 1975, US NAS 1977, Ferris 1978, Dawson and Schenker 1979, US EPA 1982, US EPA 1984, Lindvall 1985). The specific effects of NO_2 have been studied in animals, tissues and cells, in controlled human experiments, and in epidemiologic studies.

Recently, the WHO has reviewed the literature on the relation between NO_2 exposure and health effects. The following conclusions are extracted from WHO (1987):

EVALUATION OF HUMAN HEALTH RISKS

Exposure

Levels of nitrogen dioxide vary widely, since frequently a continuous baseline level is present, with peaks of higher levels superimposed. Natural background levels range from 0,4 to 9,4 µg/m³ (0,0002-0,005 ppm). Outdoor Urban levels have an annual mean ranging from 20 to 90 µg/m³ (0,01-0,05 ppm) and an hourly mean ranging from 240 to 850 µg/m³ (0,13-0,45 ppm). Levels indoors where there are unvented gas combustion appliances may average more than 200 µg/m³ (0,1 ppm) over a period of several days. A maximum 1-hour peak may reach 2000 µg/m³ (1 ppm). A maximum-per-minute peak may reach 4000 µg/m³ (2,1 ppm).

Critical concentration-response data

Concentration-response data are only available from animal studies. Thus, this section will focus on lowest-observed-effect levels and their interpretation.

Short-term exposure effects. *Available data from animal toxicology experiments rarely indicate effects of acute exposure to nitrogen dioxide concentrations of less than 1880 µg/m³ (1 ppm). Normal individuals exposed at rest or with light exercise for less than 2 hours to concentrations above 4700 µg/m³ (2,5 ppm) experience pronounced decrements in pulmonary function. The lung function of subjects with bronchitis is affected by a*

5-minute exposure to 2820 μg/m^3 (1,5 ppm) and such people are usually as responsive to nitrogen dioxide as normal subjects. A wide range of findings has been reported; one study observed no effect due to a 75-minute exposure to 7520 μg/m^3 (4 ppm), while another showed an increase in airway resistance after a 20-minute exposure to 500μg/m^3 (0,26 ppm).

Asthmatics are likely to be the most sensitive subjects, although uncertainties exist in the health data base. The lowest effects on pulmonary function were reported from two laboratories that exposed mild asthmatics for 30 minutes to a nitrogen dioxide concentration of 560 μg/m^3 (0,3 ppm) during intermittent exercise. One of these studies indicates that nitrogen dioxide can increase airway reactivity to cold air in asthmatic subjects. In most experiments involving a nitrogen dioxide concentration of 190 μg/m^3 (0,1 ppm) for 1 hour, the pulmonary function of asthmatics was not changed significantly.

Nitrogen dioxide increases bronchial reactivity as measured by pharmacological bronchoconstrictor agents in normal and asthmatic subjects, even at levels that do not affect pulmonary function directly in the absence of a bronchoconstrictor. For example, normal subjects exhibit an increased responsiveness to histamine after acute exposure to a nitrogen dioxide concentration of 910 μg/m^3 (0,48 ppm). Since the actual mechanisms are not fully defined and nitrogen dioxide studies with allergen challenges showed no effects at the lowest concentration tested (190 μg/m^3, 0,1 ppm), accurate evaluation of the health consequences of the increased responsiveness to bronchoconstrictors is not yet possible.

Long-term exposure effects. *Studies with animals have clearly shown that several weeks to months of exposure to nitrogen dioxide concentrations of less than 1880 μg/m^3 (1 ppm) cause a plethora of effects, primarily in the lung, but also in other organs such as the spleen, liver and blood.*

Both reversible and irreversible lung effects have been observed. Structural changes range from a change in cell types in the tracheobronchial and pulmonary regions (lowest reported level 640 μg/m^3; 0,34 ppm) to emphysema-like effects (lowest reported level 190μg/m^3 with peaks of 1880 μg/m^3; 0,1 ppm, peaks of 1 ppm). Biochemical changes often reflect the cellular alterations (lowest reported level 380-750 μg/m^3; 0,2-0,4 ppm). Nitrogen dioxide levels as low as 940 μg/m^3 (0,5 ppm) also increase susceptibility to bacterial infection of the lung.

There are no epidemiological studies related to outdoor exposures that can be used to evaluate quantitatively the risk of exposure to nitrogen dioxide. Homes with gas-cooking appliances have peak levels of nitrogen dioxide that are in the same range as levels causing effects in animal and human clinical studies. Many of the epidemiological studies of adults and children have shown no significant effect of the use of gas-cooking appliances on either respiratory symptoms or lung function. Nevertheless, a few have shown significant relationships in various subgroups, so that the precise relationship between health and gas-cooking (and by implication, nitrogen dioxide) remains unclear.

Health risk evaluation

Small, statistically significant, reversible effects have been confirmed in mild asthmatics exercising intermittently during a 30-minute exposure to a nitrogen dioxide concentration of 560 $\mu g/m^3$ (0,3 ppm). The sequelae of repetitive exposures of such individuals are not known. However, animals exposed for 1-6 months to nitrogen dioxide concentrations in the range of 190-940 $\mu g/m^3$ (0,1-0,5 ppm) show changes of lung structure, lung metabolism and lung defences against bacterial infection. Further exposure of animals can lead to emphysematous changes. Thus, it is prudent to avoid repetitive exposures in man, since repetitive exposures in animals lead to adverse effects. Animal toxicology studies and epidemiological studies suggest that peak concentrations contribute more to the toxicity of nitrogen dioxide than does integrated dose (the product of concentration and time of exposure).

The recommendation of a guideline is complicated by difficulties in establishing an appropriate margin of protection with regard to nitrogen dioxide. On the one hand, the replicated studies of asthmatics exercising during exposure to 560 $\mu g/m^3$ (0,3 ppm) indicate a change of about 10% in pulmonary function; although statistically significant, this change is within the range of physiological variation and therefore is not necessarily adverse. Furthermore, a number of epidemiological studies of relatively large populations exposed indoors (in kitchens) to 1-hour peak levels of nitrogen dioxide greater than 500 $\mu g/m^3$ (0,26 ppm) have not provided consistent evidence of adverse effects. Animal studies do not provide substantial evidence of biochemical, morphological or physiological effects in the lung following a single acute exposure to concentrations in the range of the lowest-observed-effect level in man. On the other hand, the mild asthmatics chosen for the controlled exposure studies do not represent all asthmatics and there are likely to be some individuals with greater sensitivity to nitrogen dioxide. Furthermore, subchronic and chronic animal studies do show significant morphological, biochemical and immunological changes.

In addition, there is a published study of the effect of a 20-minute exposure to a nitrogen dioxide concentration of 460 $\mu g/m^3$ (0,24 ppm) on airway resistance of normal subjects, and one abstract describing increased sensitivity to a bronchoconstrictor in asthmatic and normal subjects after a 1-hour exposure to 190 $\mu g/m^3$ (0,1 ppm).

3. Air Quality Standards and Guidelines

Table 1 summarizes air quality standards and guidelines for NO_2 adopted by various countries and organisations. Though most air quality standards and guidelines have been developed to evaluate outdoor air pollution levels, they may also provide a framework for a first evaluation of indoor air quality. The guideline values issued by WHO in 1987 and the MIK values defined in the FRG (all boldface in table 1) do, however, refer to both outdoor and indoor air, and must therefore be considered as most pertinent for the scope of this report.

Table 1. Air quality standards for NO_2 adopted by various countries and organisations

Country or organisation	Averaging time	Concentration [µg/m³]	Additional conditions
WHO	1 hour	190-320	Not to be exceeded more than once per month
	1 hour	**400**	**Maximum guideline value 1987**
	24 hours	**150**	**Maximum guideline value 1987**
CEC	1 year	50	50 percentile of hourly averages, guideline value
	1 year	200	98 percentile of hourly averages, limit value
	1 year	135	98 percentile of hourly averages, guideline value
Denmark	1 hour	200	98 percentile limit value
	1 hour	50	50 percentile guideline value
	1 hour	135	98 percentile guideline value
Federal Republic of Germany	1 year	80	Arithmetic mean of 30 min. averages
	1 year	300	98 percentile of 30 min. averages
	30 minutes	**200**	**MIK[1] values, not to be exceeded more than once per month and by not more than threefold**
	24 hours	**100**	
Switzerland	1 year	30	Arithmetic mean
	24 hours	80	Arithmetic mean not to be exceeded more than once a year
The Netherlands	1 year	135	98 percentile of hourly averages, limit value
	1 year	175	99,5 percentile of hourly averages, limit value
	1 year	25	50 percentile of hourly averages, guideline value
	1 year	80	98 percentile of hourly averages, guideline value
USA	1 year	100	Arithmetic mean of 24-hour averages
Japan	24 hours	80-120	Maximum level

[1] MIK = Maximale Immissions Konzentration (maximum immission concentrations; issued by VDI, the Association of German Engineers)

4. Sources

Generally NO_2 is emitted from indoor combustion sources. These comprise tobacco smoke, woodstoves and fireplaces, gas appliances and kerosene heaters. In western societies gas appliances and kerosene heaters are the major contributors. Additionally, outdoor air can act as a source for indoor NO_2 pollution. In the following paragraphs the situation with respect to the distribution of some of these sources in homes is described for those European countries for which data have been made available.

4.1. The Netherlands

In the Netherlands almost all houses are connected to the national natural gas supply system. For heating, cooking and warm water supply gas appliances are widely used in Dutch homes. All heating systems have a flue to the outside so that only in the case of leaky flues a contribution can be expected.

According to a survey in 1987 (Smith et al. 1988) 88% of the families used natural gas for cooking. It is not known in how many cases a range hood is installed.

In 61% of the houses warm water is provided by a geiser, an instantaneously burning flowthrough device, mostly installed in the kitchen. In 39 % of the homes the geisers are not directly vented to the outside. This means that in 1,339 million households an unvented geiser is present.

At present unvented kerosene heaters are commercially available in the Netherlands. An active advertising campaign is going on and it is not known how many have been sold.

4.2. Federal Republic of Germany

In 1986, 36% of a total of 25 million households in the Federal Republic of Germany were connected to gas supply systems. All of these 9,1 million households are believed to use gas for cooking. Out of these, 7,25 million households (80%) also use gas for heating and 1,85 million households use geisers (see above) for hot water supply.

In Berlin (West), where natural gas from the USSR will be available in the coming years, 37% of the customers buying energy are using town gas, among them 420.000 private households. Whereas 31% of these households are fully equipped with gas appliances, the remainder (290.000 households) use gas only for cooking and hot water heating.

The use of unvented heating devices does not play a significant role.

4.3. United Kingdom

Approximately half of UK households use natural gas for heating or cooking. The latest figures available are for England only and are based on a survey in 1981. The survey showed that

40% of households used gas for central heating
47% of households used gas for water heating in winter
44% of households used gas for water heating in summer
55% of households used gas for cooking

All heating appliances connected to the gas supply are vented through flues to outside air, as are most water heaters . Small gas water heaters, gas cookers, catalytic gas heaters and paraffin heaters are, in general, not flued.

4.4. France

In France in 1986 approximately 8,3 million households were connected to the natural gas supply system. All heating appliances connected to the gas supply are vented to outside air. Only small liquid gas heaters with a relatively low emission are not flued.
More than 95% of those connected use gas, at least partially for cooking with an estimated total of 8 million appliances. For water heating purposes about 3,5 million appliances are in use, of which about 30% are not flued.

4.5. Greece

In Greece for heating, cooking and water heating the majority of households use electricity and to some extent solar heating systems, open fires and liquid petroleum gas (LPG) heaters. A gas supply system only exists in the Greater Athens Area. The synthetic (or substituted) natural gas (SNG) is produced by catalytic conversion of naphtha (category H). Only 5294 houses are connected to this supply with an average consumption of only 1 m^3 per home per day in an open fire system. The LPG heaters are unvented as are the heaters with catalytic converters which are presently on the market. For 1992 it is planned to import natural gas from the USSR and liquified natural gas from Algeria. Gas appliances are mainly imported from other European countries.

4.6 Switzerland

In Switzerland, out of the 2,5 million households some 20% are supplied with natural gas. In these households gas is mainly used for cooking - only in special cases it is used in apartments for small heaters or for water heating. In cities gas kitchens are more common than in rural districts.

4.7 Denmark

In Denmark houses are increasingly becoming connected to the natural gas supply system. Most of the gas is used for general space and water heating. Practically these sources do not contribute to indoor levels of NO_2. However, an increased use of gas stoves for cooking is also anticipated. At present about 470.000 gas stoves are estimated to be in use in Denmark representing to about 20 % of the number of households.

Unvented gas appliances for water heating exist in a limited number of mostly older buildings, but all of them should be equipped with an exhaust to outdoor air before 1990.

The use of unvented gas and kerosene heaters is probably still limited, but numbers may be increased in the future as a result of intense commercial advertising.

5. Measured NO_2 concentrations and individual exposure

Measurements of indoor concentrations or of individual exposure to NO_2 have been reported from several European countries. Even though only few of them reflect the situation in a country in a fairly representative way, altogether they give good indications of the range of the occurring indoor concentrations and of those conditions in which guideline or limit values for NO_2 may be approached or exceeded. When comparing the reported results it should be kept in mind that indoor/outdoor NO_2 concentration ratios can show a strong seasonal dependence (see e.g. Atkins et al. 1987).

5.1. The Netherlands

Since 1980, in various investigations, NO_2 concentrations have been measured in many populations of houses covering the typical housing stock in the Netherlands. The measurements were performed with Palmes diffusion tubes (Palmes et al. 1976) giving

Table 2. **Geometric means of weekly average NO_2 concentrations in various populations of houses [$\mu g/m^3$]**

Area	Number of houses	Period	Kitchen	Living room	Bed room	Personal
Arnhem/Enschede (urban)	290	10/80	74	37	-	-
Ede (suburban)	172	winter 81/82	65	36	28	-
Rotterdam (inner-city)	102	winter 82/83	88	47	41	-
Wageningen (suburban)	35	1983	62	39	29	-
Vlagtwedde (rural)	125	11/82	55	27	15	
Vlagtwedde (urban)	128	11/83	49	27	15	32[1]
	276	11/84	79	42	32	47[1]
Veenendaal (suburban)	107	4/84	28	22	16	25[1]
	86	10/84	30	24	17	24[2]
	86	12/84	30	24	16	24[2]
N.O.-Brabant (suburban)	593	2/85	40	27	18	26[2]

[1] women, [2] children

Source: Lebret (1985), Noy (1987)

weekly average concentrations (Boleij et al. 1986). The results are summarized in **table 2.** The geometric standard deviations varied from 1,4 to 2,2. The houses in the various investigations were not selected randomly. Nevertheless, the data give a good picture of the concen-tration levels in Dutch homes. Mean 24-hour average outdoor concentrations typically range from 20 to 35 $\mu g/m^3$ for the various parts of the Netherlands, while the 98-percentile ranges from 50 to 80 $\mu g/m^3$.

In order to get information on the occurrence of peak levels of NO_2, in 12 houses real-time measurements have also been made during a period of about one week (Lebret et al. 1987). The results are summarized in **table 3.**

The influence of various factors on the NO_2 levels has been studied with regression models. The results indicated that the presence of an unvented geiser had the largest effect on the NO_2 levels in the homes. The influence of gas cooking was also apparent but less important (Noy 1987).

Assuming a ratio of 6 and 1 respectively between weekly average concentrations and 1 hour and 24 hour averages, the measured levels can be compared to existing air quality standards. The exercise suggests that the NO_2 levels frequently exceed the 24-hour maximum value of the Dutch standard in up to 43% of the kitchens in Vlagtwedde. The 1-hour maximum value is exceeded in almost all kitchens.

Table 3. **Range of the maximum 1-minute, 1-hour and 24-hour average NO_2 concentration and of the mean NO_2 concentration ($\mu g/m^3$) in twelve homes**

location	maximum concentrations			
	1-minute average	1-hour average	24-hour average	overall mean concentration
kitchen	400-3808	230-2055	53-478	36-227
living room	195-1007	101-879	49-259	32-142
bedroom	57-806	48-718	22-100	16-104
outdoors				25-70

5.2. Federal Republic of Germany

There is no large randomized study in the Federal Republic of Germany concerning the concentration levels of nitrogen dioxide encountered in German homes. However, reasonable estimates of exposure levels can be obtained from a number of available studies (Seifert et al. 1984, Englert et al. 1987).

In a study carried out in Berlin in 1980/81 (Seifert et al. 1984), Palmes passive samplers were used in a series of measurements of nitrogen dioxide in the air of kitchens and living-rooms of 15 dwellings equipped with various types of gas appliances. **Table 4** shows the average and maximum NO_2 concentrations obtained in this study (48 hour averages).

The average indoor/outdoor ratio for all dwellings with gas appliances was found to be 1.2 for kitchens and 0.68 for living rooms. The respective figures for the "electric" control dwellings were 0.48 and 0.42.

In another study (Englert et al. 1987), Palmes tubes were used to determine NO_2 levels in children's rooms of 30 dwellings in Berlin in the winter of 1984/85. **Table 5** gives the results of the respective analyses together with the NO_2 levels outdoors and the personal NO_2 exposures of the 40 children living in the dwellings under study, which were determined simultaneously. The values given in Table 5 are averages over 48 hours except at weekends when 72 hour sampling periods were used.

Table 4. Average and maximum NO_2 concentrations in 15 German homes (All values are in $\mu g/m^3$ and cover a sampling period of 48 hours)

Nitrogen dioxide concentration		
Equipment	Average	Maximum
GS, GH, GHW		
kitchen	50	190
living-room	27	72
GS, CH		
kitchen	48	109
living-room	29	72
CH, ES, GHW		
kitchen	26	61
living-room	21	54
GH, ES		
kitchen	22	41
living-room	21	82
CH, ES		
kitchen	20	67
living-room	17	67

GS = Gas stove GH = Gas heating
ES = Electric stove CH = Central Heating
GHW = Gas applicance for hot water preparation

Table 5. Synopsis of exposure conditions of 40 children in Berlin (West) from December 1984 to March 1985

Month	December	January	February	March
Indoor temperature (°C)	19.1	19.0	19.1	19.4
Relative humidity (%)	43	35	35	40
NO_2 (µg/m^3)				
indoors	18	15	16	20
personal	21	20	17	24
outdoors	43	54	44	49
SO_2 (µg/m^3) outdoors	120	190	100	100
outdoor temperature (°C)	0	-4	-3	2

Representative information on short-term peak levels of NO_2 in homes is scarce due to the fact that, for technical reasons, such information is difficult to obtaine under real-life conditions.

In a smaller study, in which 4 homes were visited for one day each late in 1981, NO_2 peak concentrations approaching 300 µg/m^3 with maximum 30 min. concentrations around 150 µg/m^3 were measured (Prescher, un-published).

Recently, NO_2 concentrations were recorded continuously over a period of up to 2 weeks in several homes (Englert et al. 1986, Englert et al., unpublished). At the same time, Palmes passive samplers were exposed for 2 or 3 days. The monitors were located in the children's rooms to reflect as much as possible the personal exposure of the children. Some of the results of this study permit an insight into the relationship between peak and average exposure and may be summarized as follows:

- In houses with gas kitchens, 10 min. and 1 hour averages of the NO_2 concentration differ by not more than about 40% whereas daily or longer averages may be from less than 3 times to more than 7 times smaller than peak values of the 10 minute averages. These results reflect a situation (children's rooms) where the most important source (gas cooker) is not in the measurement room itself. If the source is in the measurement room the differences may vary even more, as can be concluded from the results for kitchens and living rooms in table 3. It appears, therefore, difficult to predict peak concentrations from 24 hour or longer term average values. Such prediction would only be possible with sufficient knowledge (and regularity) of the occupants' life style - if at all.

- In houses with electric kitchens (i.e. without strong sources of NO_2) passive samplers averaging over 48 hours or even longer periods provide a good estimate of real exposure to NO_2. In fact, the variation of NO_2 concentrations in gas-free homes is small and reflects ambient concentrations. In these conditions short-term peaks of the NO_2 concentration usually do not occur.

5.3. United Kingdom

The principal investigations of NO_2 levels in UK homes have been those carried out by Melia et al. (1978) and Atkins et al. (1978, 1980). Generally the highest levels of NO_2 were recorded in the kitchens of homes using gas cooking, the average levels being approximately four times those in other parts of the houses. Atkins et al. (1978), found weekly mean levels of 105±49 µg/m^3 in the kitchens of eleven homes using gas cooking and 17±8 µg/m^3 in seven homes with electric cooking. The maximum average value recorded over a period of one week was 213 µg/m^3 in a house with gas cooking (49 µg/m^3 for electric cooking) although values in excess of 950 µg/m^3 were found over periods of 1-6 hours during intense cooking activity. Melia et al. (1978) found hourly average concentrations of 137 µg/m^3 in the kitchens of two homes with gas cooking and 18 µg/m^3 in two homes with electric cooking.

Atkins et al. (1980) have also measured NO_2 levels in six houses where unflued paraffin heaters were in operation and where there were no other significant sources. Measurements were made over a 9 day sampling period where the heater was in operation for 12 hours per day. The average NO_2 concentrations found were 302 ± 184 µg/m^3 in the room containing the heater and 84 ± 80 µg/m^3 elsewhere in the house. The maximum concentration found was 735 µg/m^3. Further studies of NO_2 levels in rooms heated with paraffin heaters are currently underway in the UK.

5.4. France

Table 6. Mean, minimum and maximum values of 24 hour average concentrations of NO_2 [µg/m^3] in nine homes in Paris

	Mean		Range	
	outside	inside	outside	inside
Summer, 5 homes (3 measurements/home)	33	31	9 - 87	4 - 100
Winter, 9 homes (3 measurements/home)	34	34	17 - 76	8 - 121

One study has been performed in the greater Paris area in a total of 9 homes of employees of the Laboratoire d'Hygiène de la Ville de Paris. In all homes gas was used for cooking except one home which had gas heating. Measurements were taken in the living room or in the entrance of the apartment. Simultaneously 24 hour average measurements were carried out indoors and outdoors. Preliminary results are given in **table 6.**

5.5. Greece

At present no measurements are available for NO_2 concentrations in homes. Results of a recently started project will become available by the end of 1988.

5.6 Switzerland

In the framework of a study of respiratory symptoms in pre-school children, the nitrogen dioxide concentrations were measured in a total of 1225 apartments by means of passive samplers in indoor air (living room and children's room) and outdoor air (Ackermann et al., 1988). Daily symptoms were recorded by parents on diary form during 6 week periods evenly distributed over a year, each family participating during one period. Passive samplers were changed each week. The frequency of respiratory symptoms per child and day was found to increase with increasing levels of NO_2 measured outdoors. This relationship remained significant ($p<0.001$) in a multiple regression model in which the factors smoking, origin, indoor air pollution, age and sex, season and parents' appreciation of air pollution in the living site were taken into account. No significant influence of cooking and smoking could be detected.

Table 7 summarizes the average NO_2 concentrations. 32% of the examined apartments were equipped with a gas kitchen, in 2% there was a gas heater and in 41 % of all apartments at least one person smoked.

As shown in the table, in apartments with gas kitchens the measured NO_2 concentrations were on the average 20 $\mu g/m^3$ higher than in apartments with electric kitchens. The NO_2 passive samplers were not located in the kitchen but in the living or children's room so that an average concentration in these rooms was measured.

Attention has to be paid to the fact that the outdoor NO_2 concentrations of apartments with gas kitchens were also slightly higher; the explanation for this is that gas kitchens are more often found in cities (with higher outdoor air pollution) than in rural districts (with lower outdoor air pollution). The relation between indoor and outdoor air NO_2 concentration was, however, significantly higher in apartments with gas kitchens than in apartments with electric kitchens. In apartments with smokers, the NO_2 concentrations were on an average by 5 $\mu g/m^3$ higher than in non-smoker apartments. Here too, the outdoor concentrations with smoker families were slightly but not significantly higher than with non-smoker families. Again, considering the relationship between indoor and outdoor NO_2 concentrations, the percentage of the indoor concentrations was, however, higher in smokers' apartments.

Table 7. Nitrogen dioxide concentrations in the living rooms of smoker/non-smoker apartments with gas kitchens or electric kitchens.

Source	Number of dwellings	NO_2 concentration ($\mu g/m^3$)				Relation[3] Indoor/ Outdoor (%)
		Indoor yearly mean[1]	SE[2]	Outdoor yearly mean[1]	SE[2]	
Smoker Gas kitchen	194	40.6	2.1	48.7	1.0	84
Non smoker Gas kitchen	193	37.7	1.6	45.9	1.0	83
Smoker Electric kitchen	333	22.6	0.6	42.9	0.9	53
Non-smoker Electric kitchen	505	17.2	0.4	38.3	0.7	45

[1] of 6 week averages [2] standard error [3] yearly mean value

5.7 Denmark

No randomized studies have been performed. Non-randomized NO_x measurements have been performed in 16 houses with natural or coal gas and in a single house with an electric stove. Measured concentrations are presented in **table 8** (Jespersen, 1986). Measurements of winter and summer concentrations have been performed in another study, but have not yet been published.

Table 8. NO_x concentrations [$\mu g/m^3$] in the kitchens of houses with natural gas, coal gas and electric stoves. Mean values and (in parenthesis) ranges are given for 15 minutes (maximum), 1 hour and 24 hour averages.

Source	15 minutes	1 hour	24 hours
Natural gas	500 (173-874)	318 (115-722)	62 (41-111)
Coal gas	263 (505-662)	137 (85-194)	45 (26-70)
Electricity	25	17	13

6. Preventive measures

In general the NO_2 levels indoors can be reduced by the following measures:

- direct exhaust to the outside
- improved general ventilation
- replacement with appliances having lower or zero NO_x emission
- emission reduction

Basically the last option is the best one, possibly in combination with one of the others . Bartelds (1986) recently has reviewed the literature on emission reductions of domestic gas appliances, particularly by clean combustion techniques. He concludes that even though the principles of clean combustion are well-known, no or little experience in the application of clean combustion techniques in domestic appliances is available. In principle the emissions of NO_x and CO from domestic appliances can be reduced by more than 75% at relatively low costs, as was shown for devices with radiant burners. Recommendations are made in the report on how to reach commercial maturity for applicances with clean combusion. To this end a large effort in appliance development is necessary.

7. National policies

7.1 The Netherlands

In 1986 a Parliamentary Memorandum on Indoor Environmental Policy was released by the Ministry of Housing, Physical Planning and Environment. Two items from the policy intentions described in the Memorandum are given below; one on the general approach and the other on gas appliances.

General approach

Goverment policy is based on tackling the problem of indoor environmental pollution at source. An effective policy requires emission-control measures to be based on insight into emissions from the respective sources, distribution, exposure and risk. This involves the following steps:

a. Identification of the pollutant and measurement of typical concentrations.

b. Estimation of exposure to and toxicological characterization of the individual components and compounds. The effects of long-term exposure to low concentrations and short-term exposure to peak concentrations are major areas of inquiry.

c. Emission characteristics and distribution mechanisms. Special areas of concern here include differences in the effects of continuous and intermittent emissions from either point or diffuse sources inside the dwellings or in the immediate vicinity, such as flueless water-heaters, contaminated soil or the existence of agents of biological origin (e.g. pests, moulds, allergens and so on).

d. Selection of emission-control measures depending on the situation, building construction and occupant-related factors. Some measures will be possible only while dwellings are being built, whereas others can be applied while dwellings are being renovated.

Gas appliances and heat-producing appliances

The improvement of existing gas and heat-producing appliances has priority. Among the technical possibilities for improving indoor air quality are

- the optimization of combustion techniques
- making sure appliances are leak-proof
- the use of properly sealed flues for the exhaust of flue gas and
- limiting the use of those fuels which cause the most pollution.

The importance of regular maintenance will also be stressed in the information provided to occupants.

7.2. Federal Republic of Germany

According to the information given in Section 4, gas is used for cooking in 9,5 million households. With an average occupancy of 2,4 persons/household in the Federal Republic and of 1,8 persons/household in Berlin, about 22 million persons are subject to potentially elevated indoor NO_2 concentrations.

In the Federal Republic of Germany, the concept of MIK values (Maximum Immission K(c)oncentrations) issued by the Association of German Engineers (VDI) has been developed to set health oriented guide values for the protection of the general population against harmful effects of air pollution. In the course of the last 20 years, MIK values have been set for organic and inorganic gases. The MIK values for NO_2 have been reviewed recently, and a 30 minutes value of 200 $\mu g/m^3$ has been issued as well as a 24 hours value of 100 $\mu g/m^3$ (VDI 1985). These values should not be exceeded more than once per month and then by not more than three times the respective value. Since MIK values are based on health effect considerations, they apply to any kind of inhaled air, be it outdoors or indoors.

For the time being the emission rate of NO_2 from gas stoves is not regulated nor are there regulations concerning the installation of hoods for such stoves.

In contrast, all exhaust gases from other gas appliances e.g. gas heating devices have to be delivered into the chimney or directly into outdoor air. Special regulations exist which prescribe that a sufficient amount of air be available for replacement and which contain a number of requirements for technical safety.

7.3. United Kingdom

It is recognised in the UK that levels of NO_2 in homes using gas for cooking, or where unflued paraffin heaters are used can often exceed ambient levels. At present the significance for the health of occupants of exposure to these higher levels of NO_2 in the home is unclear, and the need for further research is being considered.

7.5. France

As little information on exposure to NO_2 in the domestic environment is available in France, studies seem necessary. Improvement of combustion techniques, venting with a flue to the outside and education of the general public could reduce the number of critical cases with high exposure to NO_2. At present no special technical measures nor regulations are envisaged to limit the emissions of NO_2.

7.5. Greece

The problem of indoor air quality is recognized by the Ministry of Health, which now supports several projects for monitoring indoor pollutants (NO_2, formaldehyde, radon, asbestos). At the moment no legislative activities are in progress, because the problem is not yet clearly defined.

7.6 Switzerland

There are recommendations by the Swiss Gas and Water Industry Association (SAWA) for the installation of gas appliances and for the house supply systems. These recommendations include amongst others:

- requirements for unvented gas devices
- requirements for flues to the outside air, depending on the room volume.

Hence it follow that

- unvented cookers are admissable under normal airflow conditions
- unvented flow heaters are only admissable in rooms over 60 m^3 (they may under no circumstances be used in bathrooms and shower cabinets).

7.7 Denmark

The Ministry of Environmental Protection has established standards and guidelines for NO_2 in outdoor air. No regulations exist so far for indoor air the responsibility for which is in the hands of the Ministry of Health in collaboration with the Ministry of Housing.

Existing regulations require that installations for space and water heating are equipped with direct ventilation of all combustion gases to outdoor air through chimneys or ventilation ducts.

Rules concerning the ventilation of kitchens or other rooms with gas installations are issued by the Ministry of Public Works. Most of these rules are intended to reduce the risk of CO exposure, but will protect against other combustion gases as well.

Regarding gas stoves, recent rules require that all new stoves should be equipped with a range hood. A special organization (DGP) exists for the control and approval of all gasfired burners and appliances.

Written information and television publicity produced and distributed by the Ministry of Housing outline the risks of exposure to combustion gases and the methods of reducing it. During the last three years a working group established by the government has prepared information, initiated and evaluated research regarding emission rates from stoves and ovens, exposures, health implications, economic and technical problems of different solutions for the reduction of NO_x exposure.

8. Discussion and conclusions

In the presence of unvented gas appliances and unflued kerosene heaters indoor NO_2 concentrations may reach or even exceed existing air quality guidelines. Many studies on the influence of gas cooking and NO_2 exposure indicate that if there is an effect on human health the magnitude is likely to be small at the concentrations generally encountered in western societies. However, because the use of gas appliances is widespread and still increasing even a small effect has noticeable public health implications.

For several European countries information is lacking on the presence and the nature of gas appliances inside homes. As a first step in assessing the possibility that high NO_2 concentrations occur, national inventories should be made of the presence of unvented gas and other combustion appliances inside homes. On this basis small scale tailor-made measurement programs can be designed to get insight in the specific situation of a country. Already existing larger data bases from several countries can act as a reference.

Epidemiological studies performed so far on larger groups of the population have only given marginal evidence of a health impact of NO_2 and there are indications that very large studies would be required in order to demonstrate unequivocally such effects. Taking into account the high cost involved, such large epidemiological studies do not seem warranted. Rather smaller scale health effect studies focussing on subgroups of the population with particularly high exposures appear justified.

Existing ventilation requirements in the countries where measurements have been performed do not give sufficient protection against high exposures. However, increasing general ventilation is not the proper way to prevent high exposures. Local exhaust with hoods and flues has to be considered in the first place. Reduction of source emissions would be the most apppropriate approach and can be achieved by applying clean combustion techniques. The principles of clean combustion are known, however, a large effort in appliance development is necessary. Uncritical lowering of just NO_2 emissions may result in a shift of the problem to other pollutants.

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EUR 12219 — European concerted action
Indoor air quality and its impact on man.
COST Project 613:
Indoor pollution by NO_2 in European countries.

The Community-COST Concertation Committee

Luxembourg. Office for Official Publications of the European Communities

1989 — I-VI, 25 pp. — 21.0x29.7 cm

Series: Environment and quality of life

EN

The report summarizes information on indoor pollution by nitrogen dioxyde (NO_2) in European countries participating in the concerted action "Indoor Air Quality and Its Impact on Man" (COST project 613). Major scope of the report is to give concise information to people involved in research planning, policy making and regulatory activities and to help to identify a European view of the issue.
The summary includes a short review of health effects of NO_2 and of existing air quality guidelines and standards. For those countries for which information has been made available the more important sources, occurring indoor concentrations and national policies have been collated. Preventive measures are briefly discussed and research needs are identified.