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INSUFFICIENCY OF NATURAL VENTILATION AGAINST NOx CONCENTRATIONS CAUSED BY DOMESTIC GAS COOKERS

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ABSTRACT

Spanish regulations, like those of other countries, lay down various criteria for the permanent ventilation opening which must exist in premises containing gas-powered domestic food cookers.

There is growing concern as to the effects of NOx on the health of weaker people such as children old people and those suffering from respiratory ailments, who spend most time at home.

The paper shows the results obtained and the solutions proposed in our investigation of more than 70 dwellings in the Basque Country, Cantabria and Burgos in northern Spain, using approved and calibrated measuring devices. The investigation shows that regulations are often breached, and also that peaks of NOx concentration can occur relatively quickly even when the amount of these pollutants emitted by cookers is below the limits approved by renowned research institutions. As might be expected, the problem of dissemination is also present, causing pollutants to be carried into other parts of the home.

This shows that ventilation criteria in these cases should be based on CO_2 levels, as they usually are, but on NOx levels.

Independently of the above, in some cases inadmissible CO levels were found (for known reasons) which are not prevented either by the present regulations.

The paper also gives some results from dwellings with extractor devices, which have proved inadequate in some cases.

The relevant authorities in our area have been informed. Part of this work has been published in specialist journals and reported in lectures to professional associations, with proposals for solutions to prevent damage to health and adverse economic effects.

1.- NOx AND HUMAN HEALTH

NOx are produced by the combustion of fossil fuels, including natural gas and liquid petroleum gas. Nitrogen oxides found in indoor air in dwellings may come from outside air, from tobacco smoke and from the aforesaid fuels.

Of the wide range of products included under the heading of NOx, we studied only NO and NO_2, as these are the ones usually found in dwellings. Guideline figures are based on NO_2, because of its toxicity.

NO is oxidised rapidly by ozone. Altshuller (1) calculated that 50% of NO turns into NO_2 in less than one minute. This is based on concentrations of 0.1 ppm, and the presence of 0.1 ppm of O_3.

The annual average concentration of NO_2 in outdoor urban air is 0.01-0.05 ppm, but maximum levels of 0.45 ppm in a half hour period and 0.21 ppm in 24 hours can be found. There are peaks during the day, corresponding to increased traffic volumes in the rush-hour.

Nevertheless, indoor sources such as cigarettes and combustion products from domestic appliances are more influential in individual exposure. In dwellings with gas-powered domestic appliances with no conduits for extracting combustion products, NO_2 concentrations can be greater than outside.

Research into the effects on health of exposure to NO_2 includes controlled clinical studies, observation of effects on experimental animals and epidemiological studies. This allows the risk to health to be evaluated. This risk can be summed up as follows: slight asthmatics suffer some small, reversible effects if they are exposed while active to concentrations of 0.3 ppm for 30 minutes. Tests on animals indicate that repeated exposure leads to changes in the structure and metabolism of the lungs and in the defences against bacterial aggression. Toxicological and epidemiological studies on animals suggest that peak concentrations contribute more to the toxicity of NO_2 that overall doses.

The largest American study (2), covering schoolchildren aged between 6 and 10 in six cities, showed that children living in houses with gas-powered cookers were more likely to suffer respiratory ailments before they reached the age of two.

Various studies have revealed an increase in resistance to the passage of air through the respiratory tract after exposure to concentrations of 0.095-0.45 ppm of NO_2 with or without a bronchio-constrictor agent (3, 4, 5, 6, 7, 8, 9, 10).

At 2 ppm of NO_2 there are substantial changes in lung functions among healthy people, though other studies show no link between exposure to NO_2 in the home and adverse effects.

The W.H.O. proposes alert levels of 400 $\mu g/m^3$ (0.25 ppm) for exposures of one hour, and 150 $\mu g/m^3$ (0.08 ppm) for exposures of 24 hours to NO_2.

2.- FIELD OF OUR INVESTIGATION

We analysed sixty-four dwellings in the following areas:

a) Bilbao and the Nervión river area (Basque Country): a highly industrial and service area. The dwellings analysed were high quality constructions in industrial cities.

b) The Encartaciones area of Vizcaya (Basque Country): this area is characterised by farming and mountain agriculture. The dwellings visited were rural dwellings in the foothills of the mountains and flats in towns in the valleys.

c) The eastern coast of Cantabria: a tourist area with several concentrations of holiday homes belonging to people from the Bilbao area.

d) The Las Merindades area of northern Burgos province and the south of the Cantabrian mountains: an area characterised by long-established towns with arable farms and mountain cattle farms side by side with second homes owned by people from Bilbao attracted by the pure air, rivers and mountain landscapes. The dwellings investigated here were holiday homes.

3.- MEASURING APPARATUS AND TECHNIQUES

A German-made IMR 3000P gas analyser was used to measure the emissions from the combustion of the appliances tested (cooking hobs). This is an approved device which is calibrated every year or every 1000 hours operation. It has a probe with a thermocouple which reads the composition and temperature of combustion products. These products were collected as laid down in Spanish legislation (11) via a hood supported by a 22 cm diameter aluminium container containing 3.7 kg of water. The IMR 3000P was connected to the hood, which served as a collector for combustion products.

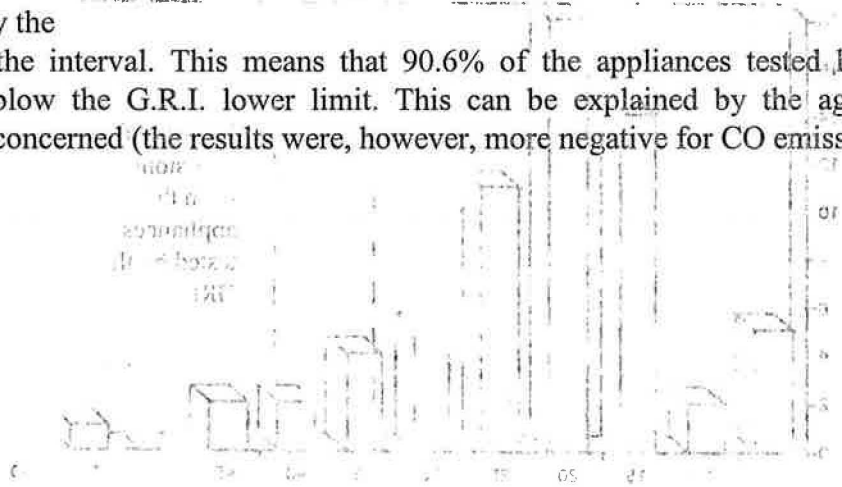
Immision levels or ambient concentrations were determined with an AC-35 analyser. This is a portable unit developed by Gaz et Electricité de France to measure NO-NOx concentrations. It works by chemi-luminescence, and has a sensitivity rating of 0.01 ppm.

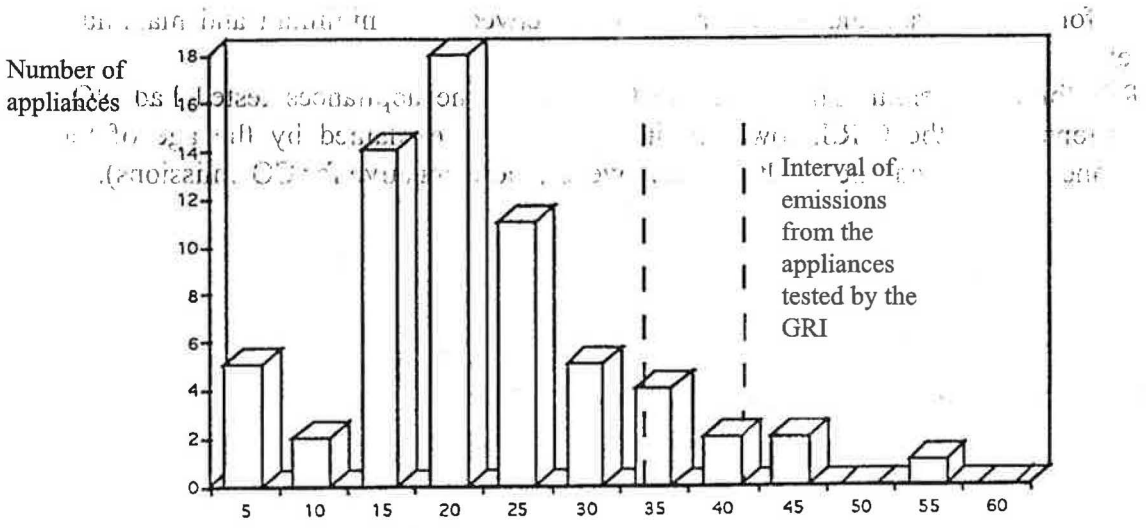
4.- APPLIANCES TESTED AND THEIR EMISSIONS

Tests were performed on sixty-four appliances of various brands and ages in the homes where they were installed. Since Spanish regulations say nothing about NOx emissions from such appliances, we had to resort to the U.S. GRI (Gas Research Institute) tests.

Graph 1 shows the distribution of appliances according to different emission intervals, and compares emissions with G.R.I. data. It can be seen that only 4.7% of the appliances tested had NOx (NO- NO_2) emissions higher than the G.R.I. upper

limit for the interval, and a further 4.7 were between the minimum and maximum levels set by the
G.R.I. for the interval. This means that 90.6% of the appliances tested had NOx emissions blow the G.R.I. lower limit. This can be explained by the age of the appliances concerned (the results were, however, more negative for CO emissions).





Graph 1

5.- FORMATION OF PEAK NOx CONCENTRATIONS DURING COOKING

In this experiment we concentrated our tests on dwellings in Portugalete (Basque Country) fitted with natural gas, which contained only gas-powered hobs. The combustion air inlet and natural draught outlet for products of combustion complied with Spanish legislation (13) in all cases. Windows were kept closed and kitchen doors open in all tests.

Outside NOx concentrations at the time of the tests were less than 0.08 ppm, and indoor levels, which were measured before starting, were negligible. The various tests were performed with the most powerful burner working at its maximum fuel consumption, and the ambient concentrations thus generated were measured after fifteen minutes' operation.

Because of the variation in the ages of the appliances tested, we proceeded as follows:

- Test nº 1: appliance with negligible CO emissions:

  We measured concentrations on the kitchen table 170 cm from the burner. As shown in Table 1, after just 15 minutes' operation the ambient NOx concentration was five times the outside level.

NOx EMISSION	10 ppm (69.62 mg/Nm^3 3% O_2)
NOx CONCENTRATION	0.041 ppm

Table 1.- NOx emissions & concentration in test nº 1

- Test nº 2: appliance with heavy NOx emissions and correct ventilation systems according to Spanish legislation (13).

Table 2 shows a peak of NOx concentration.

NOx EMISSION	41 ppm (122 mg/Nm^3 3% O_2)
NOx CONCENTRATION (1)	0.40 ppm
NOx CONCENTRATION (2)	0.18 ppm

(1) In the cooking area at a height of 150 cm

(2) On the kitchen table 180 cm from the burner

Table 2.- Results of test nº 2

- Test nº 3: Appliance with CO emissions higher than the limits set by Spanish legislation

The results shown in Table 3 are worrying, as they were obtained only fifteen minutes after the commencement of combustion.

POLLUTANT	EMISSIONS	CONCENTRATIONS
CO_2	4.7%	0.1% (A) 0.1% (B) 0.2% (C)
CO	571 ppm 1529.46 mg/Nm^3 3% O_2	2 ppm (A) 2 ppm (B) 2 ppm (C)
NOx	20 ppm 87.75 mg/Nm^3 3% O_2	0.09 ppm (A) 0.5 ppm (B) 0.12 ppm (C)

A) On the kitchen table 170 cm from the burner
B) At nostril height in the cooking area
C) In the passage next to the kitchen door, at a height of 230 cm

Table 3.- Results of Test nº 3

- Test nº 4: appliance with high CO emissions

In this case CO emissions were extremely high (over 6,000 ppm), and no emissions of NOx at all were detected. This was to be expected, in view of the "scissors effect". Table 4 shows that compliance with standard does not prevent the appearance of CO concentrations in this worrying case.

CONCENTRATION MEASURING POINT	CO_2 %	CO ppm
(A)	0.1	11
(B)	0.2	11
(C)	0.1	4

(A): at nostril height in the cooking area.
(B): on the kitchen ceiling
(C): on the kitchen table

Table 4.- Concentrations detected in test nº 4

6.- CASES WITH NO VENTILATION

Some holiday homes, either because they are in cold areas or because they were originally intended to use electric power, have no ventilation. The following test was performed in such a home in Medina de Pomar (Burgos): we lit the most powerful burner on the hob at its highest fuel consumption and measured the emissions after twenty-six minutes' operation. Table 5 shows the figures obtained

Pollutant	CO_2	CO		NOx	
		ppm	mg/Nm^3 3% O_2	ppm	mg/Nm^3 3% O_2
Emission	4.6%	330	1079	11	58.82

Table 5.- Emissions from a butane cooker in a holiday home

Ambient concentrations were measured with the windows closed and the inside doors open. The results are shown in Table 6

POLLUTANT LEVEL MEASURING POINT	T (*)	CO_2/%	CO/ppm	NOx/ppm
A	2 minutes	0.2	9	0.62
B	5 minutes	0.2	9	0.45
C	19 minutes	0.0	6	0.31
D	20 minutes	0.0	6	0.31

* Time since cooker was switched off
A Kitchen table
B Centre of living room
C Bedroom nº 1
D Bedroom nº 2

Table 6.- Ambient concentrations in an unventilated holiday home

with emissions produced by a cooker hob

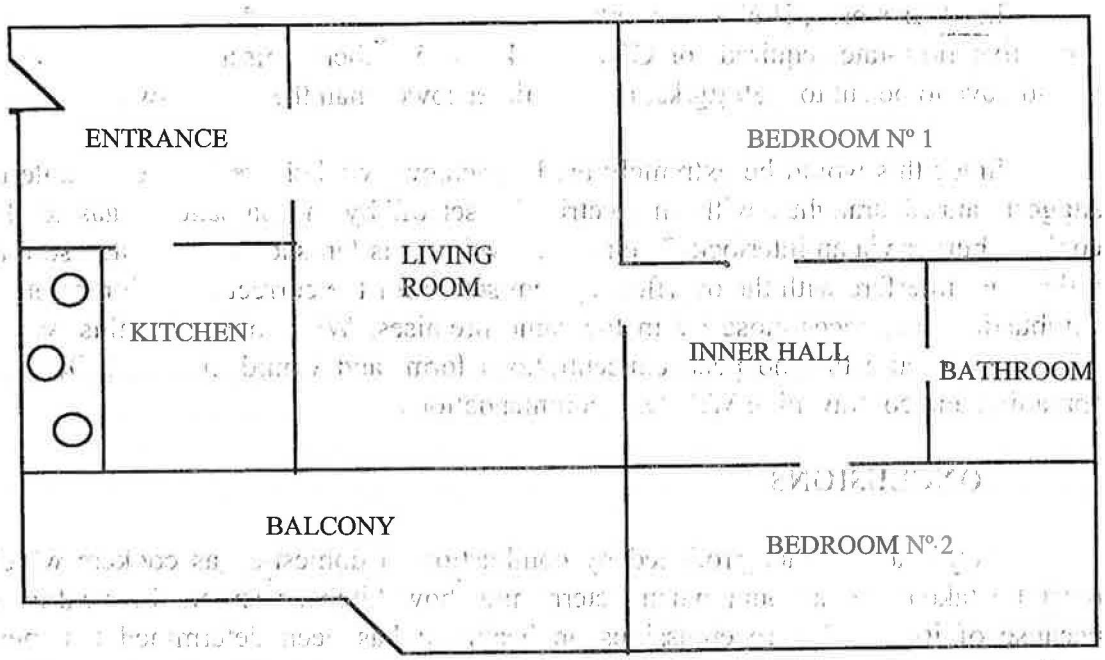


Figure 1: Floor plan of the holiday home tested

High concentrations of CO and NOx were detected in all the rooms in this unventilated house, even twenty minutes after the appliance was switched off.

Similar situations were found in farmhouses in the Encartaciones area of the Basque Country.

7.- CASES WITH VENTILATION COMPLYING WITH PRESENT REGULATIONS

Numerous tests have shown that the natural ventilation systems proposed by present legislation do not prevent the formation of peak concentrations of NOx and CO. The situation is however even worse when this ventilation is not installed, as sometimes happens because of the bad weather often suffered in the areas under study.

The problem is that the ventilation criteria laid down provide for protective air flow rates which prevent CO_2 concentrations from exceeding a set level. In many countries this level is set at 0.5%, based on outside concentrations of 0.04%.

For CO_2 emission rates of 0.0027 l/s-kW for natural gas and 0.033 l/s-kW for LPG, the flow rates to protect against CO_2 work out to 4.964 l/s-kW and 6.061 l/s-kW

respectively. If the G.R.I. emission levels for NO_2 in cooking appliances are taken as valid (9-12.5 µg/kJ) and the outside concentration is 0.05 ppm of NO_2 the protective air flow rates needed to prevent a concentration of 0.21 ppm of NO_2 one hour after the cooking appliance starts working work out to 27.25 and 37.85 l/s-kW respectively.

In other words, if NO_2 concentrations are to be controlled on the basis of the protective flow-rate required for CO_2 (4.964 l/s-kW), then emissions from cookers would have to be cut to 1.89 µg/kJ, i.e. five times lower than the G.R.I. lower limit.

Since this would be extremely hard to achieve, we believe it is reasonable to suggest fanned draught , with an electric fan set off by the passage of gas to the cooking burner via an interlock. The power level of this fan should be limited so that it does not interfere with the overflow system set up for the correct operation of other combustion appliances close by in the same premises. We believe that this would effectively ensure that no peak concentrations form, and would prevent NO_2 from spreading and contravening W.H.O. recommendations.

8.- CONCLUSIONS

NO_2 is a pollutant produced by combustion in domestic gas cookers which must be taken into account when determining how kitchens should be ventilated because of its possible repercussions on health. It has been determined that new appliances in general give off more emissions than older ones. This is the reverse of the situation as regards carbon monoxide emissions.

The case histories we have built up over several years in northern Spain show that there are peaks at which levels are by no means negligible, and that in some cases the situation gives cause for concern. Very high NO_2 concentrations have been found in cases of serious defects and lack of ventilation.

The ventilation criteria used in present legislation are based on CO_2 concentrations, and calculations using the data on NO_2 emissions from cooking appliances detected by the G.R.I. show concentrations of NO_2 far beyond those recommended by the W.H.O. We recommend ventilation criteria based on NO_2, but in this case the ventilation systems required to give a flow rate high enough to protect against NO_2 would be too big. We therefore suggest that combustion gases be collected by an individual mechanical ventilation device interlocked with the fuel gas supply to the cooking burners, with limited power and all necessary precautions to prevent interference with combustion gas evacuation in other nearby appliances.

BIBLIOGRAPHY

1.- Altshuller, A.P.- Thermodynamic considerations in the interaction of NOx (and its oxyacids) in the atmosphere. Journal of the Air Pollution Control Association, 6:97-100 (1956).

2.- Speizer, F.E.- Respiratory disease rates and pulmonary function in children associated with NO_2 exposure. American Review of Respiratory Disease, 121: 3-10 (1980).

3.-Bauer, M.A.- 0,30 ppm nitrogen dioxide inhalation potentiates exercise-induced bronch-spasm in asthmatics.- American Review of respiratory Disease, 129 : 151, 1984.

4.- Horstmann, D.H.- Pulmonary effects in asthmatics exposed to 0,3 ppm of NO_2 during repeated exercise.- American Review of Respiratory Disease.

5.- Rehn, T.- Muccociliary transport in long and nose, and airway resistance after exposure to NO_2.- Coal-Health.- Environment Project.- Stockholm, 1982.

6.- Kleinman, M.T.- Effects of 0,2 ppm de NO_2 on pulmonary function and response to bronchoprovocation in asthmatics.- Journal of Toxicology and Environmental Health, 12 : 185-826. 1983.

7.- Kagawa, J.- Respiratory effects of 2-hour exposure to ozone and nitrogen dioxide alone and combination in normal subjects performing intermittent exercise - Japanese Journal of Thoratic Disease, 17 : 765-779 (1979).

8.- Byling, G.- Effects of short-term exposure to ambient nitrogen dioxide concentrations on human bronchial reactivity and long function. European Journal of Respiratory Diseases, 66 : 205-217 (1985).

9.- Ahmed, T.- Effect of 0,1 ppm NO_2 on bronchial reactivity in normals and subjects with bronchial asthma. American Review of Respiratory Disease, 127 : 160 (1983).

10.- Orehek, J.- Effect of short-term, low-level NO_2 exposure on bronchial sensitivity of asthmatic patients. Journal of Clinical Investigation, 57 : 301-307 (1976).

11.- Supplementary Technical Instruction MIE-AG6. UNE Standard 60-755-81.

12.- Irwin H. Billick. GRI. The natural gas industry's research related to I.A.Q.- The Fifth International Conference on I.A.Q. and climate. Vol. 5. Toronto (1990).

13.- Regulations for Gas Installations in Premises for Domestic, Collective or Commercial Use (Official Gazette nº 281, 21-11-1993).

14.- Doctoral thesis: "Investigation into Improving Indoor Air Quality and into Safety of Operation of Domestic Appliances Powered by Natural Gas and/or LPG" by Dr. Víctor del Campo Díaz, supervised by Dr. Juan V. Martín Zorraquino.