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Effects of home environment on respiratory symptoms and lung function in a general population sample in North Italy

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ABSTRACT: Effects of indoor pollution exposure were evaluated in a general population sample (n=3,289) living in the Po River Delta area. Prevalence rates of chronic cough in men and dyspnoea in women were significantly higher in association with the use of bottled gas (propane) for cooking instead of natural gas (methane). Chronic cough and phlegm in men and dyspnoea in women were significantly associated with the use of a stove for heating. When combining type of heating and fuel used, in men a trend toward higher prevalence rates of chronic cough and phlegm was shown in those with stove or fan heating (regardless of the fuel); in women the trend reached statistical significance for dyspnoea. The relationship between stove (regardless of fuel) and decrease in forced expirograms was statistically significant only in women. In multiple logistic models, accounting for independent effects of age, smoking, pack-years, parents' smoking, socio-economic status, body mass index, significantly increased odds ratios were found in males for the associations of: bottled gas for cooking with cough (1.66) and dyspnoea (1.81); stove for heating with cough (1.44) and phlegm (1.39); stove fuelled by natural gas and fan or stove fuelled other than by natural gas with cough (1.54 and 1.66). In females, significantly increased odds ratios were found only for dyspnoea when associated with bottled gas for cooking (1.45), stove for heating (1.46), stove fuelled by natural gas (1.58), stove or fan fuelled other than by natural gas (1.73). Even if the exposure was assessed only by questionnaire, our results indicate that using fuels other than natural gas and heating appliances other than central heating may be related to mild adverse health effects in a general population sample.

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In the last ten years an increasing amount of work has been devoted to the health effects of indoor pollution. It has been recognized that, on average, people spend most of their time inside and a lot of pollutants can be detected in the various rooms of a house, especially in kitchens [1–4]. However, not many epidemiological surveys have investigated these effects, especially in Europe.

Effects of nitrogen dioxide (NO_2) have been investigated in children [5–9]: the use of gas for cooking or heating was associated with increased prevalence rates of cough, wheezing, acute respiratory infections, history of respiratory illness before age 2 yrs and rate of hospitalization. The use of gas was also associated with slight or no reduction in forced expiratory volume in one second (FEV_1) [6–11]. In adults, increased prevalence rates of chronic cough and phlegm and reduced FEV_1/forced vital capacity (FVC) ratios have been found to be related to gas stove usage in the USA and in the Netherlands [12–14].

Space (forced air) heaters, especially those using kerosene, may be the source of carbon monoxide (CO) indoors, which may be related to coronary artery disease, peripheral vascular disease and chronic obstructive pulmonary disease [1, 2, 15]. These heaters also produce high levels of NO_2, sulphur dioxide (SO_2), and particulates.

Although measurements of pollutant concentrations are recommended [1, 2], such measurements are neither easy, nor sufficiently inexpensive to be applied in large scale epidemiological surveys. Thus, most published reports are based on the assessement of exposure by questionnaire.

On this basis we have analysed the data of the first large scale epidemiological survey in Italy [16–19],

originally planned to assess the health effects of outdoor air pollution from a large oil-burning central power plant. The aim of the present report is to evaluate if the fuel for cooking or for heating, as well as the kind of heating, are associated with increased prevalence rates of respiratory symptoms or impaired lung function in a general population sample.

Material and methods

A randomized, stratified family cluster sample (n=3,289) of the general population aged 8–64 yrs living in the unpolluted rural area of Po River Delta (Northern Italy) has been enrolled in a longitudinal epidemiological survey. The first cross-sectional survey was carried out before the start of operation of the power plant (1982). The second survey is currently in progress. Sampling methods, population characteristics, questionnaire, and lung function tests in normals and in symptomatic subjects, were fully described elsewhere [16–19].

Briefly, each subject completed an interviewer-administered questionnaire, modified by the Italian National Research Council, from that of the American National Heart and Lung Institute (now NHLBI). For children under 10 yrs, the answers were provided by the mothers; over 10 yrs, each subject answered personally. The following symptoms were considered for analysis: chronic cough and phlegm, if the subject coughed (or had phlegm) for as much as three months of the year for at least two years; wheeze or attacks of shortness of breath with wheeze (SOBWHZ), apart from common colds; dyspnoea on exertion, if the subject had shortness of breath when hurrying on level ground or walking up a slight hill. Asthma was evaluated if the diagnosis was reported as being confirmed by a physician. There were insufficient diagnoses of emphysema or chronic bronchitis to analyse.

Other questions related to the home environment:
a) What kind of heating do you have at home: 1. fan; 2. central heating; 3. stove; 4. none. If there is heating, a1) What is the main fuel you use for heating: 1. natural gas; 2. bottled gas; 3. electricity; 4. kerosene; 5. wood; 6. coal or oil; 7. others.
b) What is the main fuel you use for cooking: (the same possible answers as a1, except kerosene).

Of 3,091 subjects with information on cooking fuel, 83% used natural gas (N), 16% bottled gas (B) and 1% wood. Regarding the 3,087 with heating fuel information, 80% used natural gas, 10% coal or oil (C), 6% kerosene (K), only 2% used wood, 1% bottled gas and less than 1% electricity. Regarding the 3,083 with information on kind of heating, 72% used central heating (C), 24% stove (S) and only 4% fan (forced air) (F). The different sources of indoor pollution were significantly interrelated, as expected: for instance, among those using natural gas or coal/oil for heating, 75% and 97% had central heating, while, among those using kerosene or wood, 88% and 73% had stove. In addition, 94% of those using natural gas for cooking used the same fuel for heating; 52% and 33% of those using bottled gas had coal/oil or kerosene for heating. We have eliminated from the analyses the classes with too few subjects and, for simplicity, we do not report here the analyses on fuel for heating *per se*.

Ninety four percent of subjects succeeded in performing acceptable forced vital capacity and derived indices (FEV_1, peak flow (PF), forced mid-expiratory flow (FEF_{25-75}), maximal expiratory flow at 50% and 25% expired volume (MEF_{50}, MEF_{75}) respectively). The values were expressed in % predicted using reference equations derived from normals within the sample [17].

Statistical analyses were performed partly on the University of Pisa Computer System (CNUCE, IBM 3081), partly on a Personal Computer (PC-AT) at the University of Arizona, using the routines of the Statistical Package of the Social Sciences (SPSS). The Chi squared distribution was used to assess the differences in symptom prevalence rates and analysis of variance (ANOVA and ONEWAY with Duncan's multirange test) was used to evaluate the differences in mean values of lung function test. A p value of 0.05 was accepted as statistically significant, even with multiple comparisions, since we considered it worthwhile not to increase the probability of false negative results (*i.e.* type II or beta error) in a screening process [20]. To account for the independent effects of different risk factors in determining respiratory symptoms, multiple logistic regression models in each sex were used, with continuous variables (age, pack-years) and categorical variables: smoking (0 = never, 1 = ever smoker), socioeconomic status (SES) (0 = high-middle, 1 = low SES), parents' smoking (0 = unexposed, 1 = exposed). When dyspnoea was analysed, another continuous variable was taken into account, *i.e.* body mass index ($kg \cdot m^{-2}$). For each symptom, logistic models were used in order to consider separately: a) the effect of fuel for cooking (0 = natural, 1 = bottled gas); b) the effect of type of heating (0 = central heating, 1 = stove or fan); c) the interaction of type and fuel for heating (0 = central heating fuelled by natural gas, 1 = central heating fuelled by bottled gas, kerosene, wood or coal/ oil, 2 = stove fuelled by natural gas, 3 = fan or stove fuelled by bottled gas, kerosene, wood or coal/oil).

Results

There were no significant differences among the various groups of indoor pollution for age, percentage of ever smokers and pack-years, either in adults or in young subjects. As expected, the presence of more polluting fuel for cooking and of a less modern heating device was significantly associated with a low SES: among those with bottled gas for cooking, 29% of male and 34% of female adults belonged to the low SES group, compared with 13% and 15% of those using natural gas; of those with stoves for heating, 28% of males and 30% of females had worse socieconomic conditions, in contrast to 12% and 15% of those using central heating. Similar figures were obtained when those under 20 yrs were analysed separately.

Prevalence rates of respiratory symptoms, according to the use of different fuels for cooking, are shown in table 1: adult males using bottled gas showed higher

Table 1. – Prevalence rates (%) of respiratory symptoms, by sex, age and cooking fuel

	Males Cooking fuel				Females Cooking fuel			
	8–19 yrs		20+ yrs		8–19 yrs		20+ yrs	
	N	B	N	B	N	B	N	B
n	328	52	942	194	352	50	956	203
Chronic cough	1	4	17	24*	3	-	6	5
Chronic phlegm	3	2	17	22	3	2	5	3
Wheeze	5	10	13	13	3	6	7	8
SOBWHZ	5	2	5	5	3	6	4	6
Dyspnoea	2	-	13	18	2	2	20	28*
Asthma	6	10	5	7	5	8	4	3

*: p<0.05 (by Chi squared). N: natural gas; B: bottled gas; SOBWHZ: attacks of shortness of breath with wheeze.

Table 2. – Prevalence rates (%) of respiratory symptoms by sex, age, type of heating, and combination of type and fuel for heating

	Males Type of heating				Combination of type and fuel for heating			
	8–19 yrs		20+ yrs		20+ yrs			
	C	S	C	S	C+N	C+B/O	S+N	F/S+B/O
n	288	77	808	283	663	142	188	137
Chronic cough	2	1	17	23*	16	22	22	21
Chronic phlegm	3	3	17	22*	16	21	22	18
Wheeze	6	1	13	15	13	11	15	14
SOBWHZ	5	4	5	3	5	5	2	5
Dyspnoea	2	-	14	13	13	17	12	18
Asthma	7	5	5	4	5	6	3	7
	Females Type of heating				Combination of type and fuel for heating			
	8–19 yrs		20+ yrs		20+ yrs			
	C	S	C	S	C+N	C+B/O	S+N	F/S+B/O
n	278	106	837	285	687	147	192	130
Chronic cough	3	4	5	7	5	5	8	5
Chronic phlegm	3	2	5	5	5	2	5	5
Wheeze	2	7*	6	9	6	9	9	7
SOBWHZ	3	5	4	6	4	5	6	5
Dyspnoea	0.7	6**	20	28*	18	27	27	29**
Asthma	5	5	4	6	4	3	7	3

**: p<0.01; *: p<0.05 (by Chi-squared). C: central heating; S: stove; C+N: central heating fuelled by natural gas; C+B/O: central heating fuelled by bottled gas, kerosene, wood or coal/oil; S+N: stove fuelled by natural gas; F/S+B/O: fan or stove fuelled by bottled gas, kerosene, wood or coal/oil; SOBWHZ: attacks of shortness of breath with wheeze.

prevalence rates of respiratory symptoms, statistically significant for cough, compared with those using natural gas; no significant difference was exhibited by those under age 20 yrs. Among females 20+ yrs, dyspnoea was significantly more prevalent in those using bottled gas.

Cough and phlegm were also significantly more frequent among adult males using stoves (table 2). When considering the combination of type and fuel for heating, there was a trend (not statistically significant) toward higher prevalence rates of symptoms (except for wheeze and SOBWHZ) among those using fuels other than natural gas, regardless of the kind of heating. Among females, dyspnoea and wheeze (only in those under age 20 yrs) were significantly more frequent in those using a stove for heating. Adult females using stoves or fans (regardless of fuel) and with central heating fuelled other than by methane had significantly higher prevalence rates of dyspnoea. Trends were similar when stratifying by smoking or by SES, but cell sizes were too small to test hypotheses.

Table 3. – Significantly different lung function tests in females 20+ yrs by type of heating, and combination of type and fuel for heating

	Type of heating		Combination of type and fuel for heating			
	C	S	C+N	C+B/O	S+N	F/S+B/O
n	784	253	642	139	174	114
FEV_1	99	97	98	101†	97	96*
FEF_{25-75}	98	93**	97	102†	93	92**
MEF_{50}	99	93**	98†	103†	94	93**
MEF_{75}	97	94	96	104	94	95
PF	100	97*	100	98	97	98

**: p<0.01; *: p<0.05 (by ANOVA, adjusting for age, pack-years and SES); †: p<0.05 (by Duncan's multirange test) in comparison to S+N and F/S+B/O; C: central heating; S: stove; C+N: central heating fuelled by natural gas; C+B/O: central heating fuelled by bottled gas, kerosene, wood or coal/oil; S+N: stove fuelled by natural gas; F/S+B/O: fan or stove fuelled by bottled gas, kerosene, wood or coal/oil; FEV_1: forced expiratory volume in one second; FEF_{25-75}: forced mid-expiratory flow; MEF_{50} and MEF_{75}: maximal expiratory flow at 50% and 25% expired volume, PF: peak flow; SES: socioeconomic status; ANOVA: analysis of variance.

Table 4. – Relationship of respiratory symptoms to home environment characteristics; odds ratios and 95% confidence intervals estimated in logistic models

Symptom	Source of exposure	OR (CI)	Confounders in the model
Males			
Chronic cough	B	1.66 (2.46–1.12)	Age, smoking, pack-years
	S	1.44 (1.98–1.04)	Age, smoking, pack-years
	S+N	1.54 (2.35–1.10)	Age, smoking, pack-years
	F/S+B/O	1.66 (2.65–1.04)	Age, smoking, pack-years
Chronic phlegm	S	1.39 (1.91–1.01)	Age, smoking, pack-years, SES
Dyspnoea	B	1.81 (2.85–1.15)	Age, pack-yrs, SES (-), BMI
Females			
Dyspnoea	B	1.45 (2.10–1.00)	Age, pack-years, BMI
	S	1.46 (1.96–1.09)	Age, BMI
	S+N	1.58 (2.34–1.07)	Age, pack-years, BMI
	F/S+B/O	1.73 (2.67–1.12)	Age, pack-years, BMI

B: bottled gas (cooking); S: stove (heating); S+N: stove fuelled by natural gas; F/S+B/O: fan or stove fuelled by bottled gas, kerosene, wood or coal/oil; SES: socioeconomic status; BMI: body mass index; (-): negative coefficient in the model.

Lung function tests in adults were analysed using analysis of variance (ANOVA) among the different indoor categories, also taking into account the effects of covariates (age, pack-years, socioeconomic condition). In both sexes, age and pack-years always explained a significant part of the variance of lung function tests, whereas SES did not. In males, mean values of lung function indices were not significantly different in the various groups of home environment characteristics. Similar results were found in females for those using natural gas and those using bottled gas for cooking. Females with a stove had significantly lower values of FEF_{25-75}, MEF_{50} and PF than those with central heating (table 3). When considering the combination of type and fuel for heating, significantly different adjusted mean values were found among the four categories for FEV_1, FEF_{25-75} and MEF_{50}. In order to assess which categories were significant, we performed analysis of variance (ONEWAY) with Duncan's multiple range test. Females with stoves fuelled by natural gas and those with stoves or fans fuelled by bottled gas, kerosene, wood or coal/oil, showed significantly lower mean values of FEV_1, FEF_{25-75} and MEF_{50} compared with those using central heating fuelled other than by natural gas. In addition,

they showed significantly lower mean values of MEF_{50} compared with those using central heating fuelled by natural gas.

The results of multiple logistic models are shown in table 4. In males, bottled gas for cooking was significantly associated with higher odds ratios for chronic cough (1.66) and dyspnoea (1.81), with respect to natural gas. Use of a stove was significantly associated with higher odds ratios for chronic cough (1.44) and phlegm (1.39), with respect to central heating. When combining fuel and type of heating, significantly higher odds ratios for having chronic cough were found for use of stove fuelled by natural gas (1.54) and of fan or stove fuelled by bottled gas, kerosene, wood or coal/oil (1.66), with respect to central heating fuelled by natural gas. Regarding the confounders in the model, age, smoking and pack-years were always statistically significant, while SES was statistically significant for phlegm and, inversely, for dyspnoea. Body mass index reached the level of significance for dyspnoea. In females, significantly increased odds ratios were found only for dyspnoea when associated with bottled gas for cooking (1.45), stove (1.46), stove fuelled by natural gas (1.58), stove or fan fuelled by bottled gas, kerosene, wood or coal/oil (1.73). In this case, age, pack-years and body mass index were statistically significant confounders.

Discussion

The results of these analyses on the effects of the various sources of indoor pollution in a large sample of a general population, living in a rural unpolluted area of North Italy, show that using a fuel different from natural gas for cooking and using a device different from central heating fuelled by natural gas may be associated with moderate adverse effects on the respiratory system. The effects appear more evident for symptom prevalence rates than for impaired lung function (only present in women). These results seem in accordance with most of the studies conducted in other European countries and in the USA, which have dealt mainly with gas cooking, regardless of the type of gas. In particular, gas cooking has been shown to be associated with a higher prevalence of respiratory symptoms/illnesses [5, 6, 8, 9, 11] and with marginally decreased lung function values [6, 7, 10] in children. In adults, associations with respiratory symptoms and, to a lesser extent, lung function impairment have been found [12–14, 21). However, some investigators [22] have found no adverse respiratory effects of gas cooking.

The higher sensitivity of respiratory symptoms, compared to lung function tests is commonly found in studies assessing the effects of outdoor pollution [23, 24]. DALES *et al.* [24] have postulated two possible mechanisms: a biological effect of chronic exposure to low level air pollution on symptoms, without physiological changes, or an increased perception of symptoms by people living in exposed areas. The latter mechanism is an unlikely contributor in exposure to indoor air pollution. In fact, the average knowledge on this matter is generally poor, especially in this rural area.

It is also a possibility that indoor pollutants act more acutely on lung function, but these changes may be more transient than the occurrence of symptoms or may be present only in susceptible subjects. Thus, a continuous monitoring of lung function would be requested, rather than a cross-sectional investigation. For example, LEBOWITZ *et al.* [25], using peak expiratory flow measured daily for at least two weeks, found a negative effect of gas stove on the lung function of susceptible subjects (asthmatics, allergic individuals, smokers).

Regarding the fuel used for cooking, we have found higher odds ratios for dyspnoea in both sexes and for cough in males using bottled gas (mixed propane) than in those using natural gas (methane). These findings were obtained after accounting for the effects of covariates such as age, active smoking, parents' smoking, SES and body mass index. Moreover, we have found higher odds ratios for cough and phlegm in men and for dyspnoea in women using stove (regardless of the fuel) for heating, after accounting for the same set of covariates in multiple logistic models.

It is not the purpose of this study to speculate upon the underlying mechanisms in detail, due to the approximate estimate of indoor exposure accomplished by the questionnaire. However, apart from the possible differences between males and females in perceiving and reporting respiratory symptoms (which may explain why phlegm is generally a male characteristic and dyspnoea a female characteristic [19]), it is of note that inconsistent results are not unusual in the field of indoor pollution studies. For example, COMSTOCK *et al.* [13] found an association between the use of gas for cooking and respiratory symptoms, as well as lung function, in men, but not in women. Recently, JEDRYCHOWSKI *et al.* [26] have found a dose-response relationship of different symptoms such as dyspnoea, chronic cough and, especially, phlegm with time spent in the kitchen by elderly women. In addition, those investigators who have measured NO_2 indoor [27] have found that it is measurable in all the rooms of a house and that sometimes its threshold limit value is also exceeded in the living room. Thus, it is a potential risk for all of the members of the household.

As a possible explanation of our findings, we might hypothesize, on the one hand, that there may be a greater production of CO and NO_2 by propane than by methane. In fact, bottled gas ovens are generally less efficient than those using natural gas, and they are not mandatorily checked by an official technician. On the other hand, an important role might be played by difference in climatic conditions (ventilation, humidity, temperature) produced by the different kinds of heating. It is of note that MELIA *et al.* [28] found in children a significant positive association between the prevalence of one or more respiratory conditions and relative humidity. In addition, BRUNEKREEF *et al.* [29] have reported in children significantly increased odds ratios for cough, wheeze, asthma and other respiratory illnesses associated with at least one questionnaire indicator of home dampness.

In conclusion, our results confirm that home environment characteristics may be associated with mild adverse

health effects related to symptoms and, to a lesser extent, to lung function. Thus, they should be taken into account in multivariate analyses for factors affecting the natural history of chronic obstructive lung disease. Moreover, these findings would suggest the implementation of air pollution monitoring studies in subsets of houses with different types of indoor environments, especially those inhabited by susceptible individuals (*e.g.* asthmatics, chronic bronchitics, allergic subjects, smokers), in order to evaluate the possibility of a dose-response relationship between home environment characteristics and respiratory symptoms and lung function.

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Effets de l'environment domestique sur les symptômes respiratoires et la fonction pulmonaire dans un échantillon de la population générale de l'Italie du Nord. G. Viegi, P. Paoletti, L. Carrozzi, M. Vellutini, L. Ballerin, P. Biavati, G. Nardini, F. Di Pede, T. Sapigni, M.D. Lebowitz, C. Giuntini.

RÉSUMÉ: Les effets de la pollution domestique ont été évalués dans un échantillon de population générale (n=3289) vivant dans le delta du Pô. Les taux de prévalence de toux chronique chez les hommes et de dyspnée chez les femmes s'avèrent significativement plus élevés en cas d'association avec l'utilisation de gaz en bonbonne (Propane) pour la cuisine, au lieu de gaz naturel (methane). La toux chronique et l'expectoration chez les hommes, et la dyspnée chez les femmes, sont associées de façon significative à l'emploi de poêles pour le chauffage. En combinant le type de chauffage et le combustible utilisé, chez les hommes on note une tendance vers des taux de prévalence plus élevés de toux chronique et de crachats chez ceux qui emploient les poêles ou les ventilateurs pour le chauffage, quel que soit le comburant utilisé; chez les femmes, la tendance atteint une signification statistique pour la dyspnée. La relation entre le poêle (indépendamment du comburant) et la diminution des expirogrammes forcés n'est statistiquement significative que chez les femmes. Dans les modèles logistiques multiples, prenant en compte les effets indépendants de l'âge, du tabagisme, du nombre d'années-paquet, du tabagisme parental, de l'état socio-économique, de l'index de masse corporelle, on trouve des rapports de risques accrus de manière significative chez les hommes pour l'association avec l'emploi de gaz en bonbonne pour la cuisine avec la toux (1.66) et la dyspnée (1.89), de l'emploi de poêles pour le chauffage avec la toux (1.44) et les crachats (1.39), et enfin de l'emploi de poêles approvisionnés par le gaz naturel et de ventilateurs ou de poêles approvisionnés par des gaz autres que naturels avec la toux (1.54 et 1.66). Chez les femmes, des ratios de risques accrus ne sont décelés que pour la dyspnée en association avec l'emploi de gaz en bonbonne pour la cuisine (1.45), de poêles pour le chauffage (1.46), de poêles approvisionnés par le gaz naturel (1.58), de poêles ou de ventilateurs approvisionnés par des gaz autres que les gaz naturels (1.73). Même si l'exposition a été appréciée seulement par questionnaire, nos résultats indiquent que l'utilisation de combustibles autres que le gaz naturel et de techniques de chauffage autres que le chauffage central, peuvent être en relation avec des effets santé défavorables, mais peu marqués, (dans un échantillon de population générale).

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