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Bénédicte Jacquemin, Jordi Sunyer, Bertil Forsberg, Inmaculada Aguilera, David Briggs, Thomas Götschi, Joachim Heinrich, Kjell Torén, Danielle Vienneau, Nino Künzli

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B Jacquemin,[1] J Sunyer,[1,2] B Forsberg,[3] I Aguilera,[1] D Briggs,[4] T Götschi,[5] J Heinrich,[6] K Torén,[7] D Vienneau,[4] N Künzli[1,5,8]

[1] Municipal Institute of Medical Research, Barcelona, Spain; [2] Universitat Pompeu Fabra, Barcelona, Spain; [3] Umeå University, Umeå, Sweden; [4] Imperial College, London, UK; [5] University of Southern California, Los Angeles, California, USA; [6] GSF Institute of Epidemiology, Munich, Germany; [7] Sahlgrenska University Hospital, Göteborg, Sweden; [8] Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain

Correspondence to: B Jacquemin, Inserm U780, Epidémiologie et Biostatistique, 16, avenue Paul Vaillant Couturier, 94807 Villejuif Cedex, France; benedicte.jacquemin@inserm.fr

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ABSTRACT

Introduction: Annoyance caused by air pollution has been proposed as an indicator of exposure to air pollution. The aim of this study was to assess the geographical homogeneity of the relationship between annoyance and modelled home-based nitrogen dioxide (NO_2) measurements.

Methods: The European Community Respiratory Health Survey II was conducted in 2000–1, in 25 European centres in 12 countries. This analysis included 4753 subjects (from 37 in Tartu, Estonia, to 532 in Antwerp, Belgium) who answered the annoyance question and with available outdoor residential NO_2 (4399 modelled and 354 measured) including 20 cities from 10 countries. Annoyance as a result of air pollution was self-reported on an 11-point scale (0, no disturbance at all; 10, intolerable disturbance). Demographic and socioeconomic factors, smoking status and the presence of respiratory symptoms or disease were measured through a standard questionnaire. Negative binomial regression was used.

Results: The median NO_2 concentration was 27 $\mu g.m^{-3}$ (from 10 in Umeå, Sweden, to 57 in Barcelona, Spain). The mean of annoyance was 2.5 (from 0.7 in Reykjavik, Iceland, to 4.4 in Huelva, Spain). NO_2 was associated with annoyance (ratio of the mean score 1.26 per 10 $\mu g.m^{-3}$, 95% CI 1.19 to 1.34). The association between NO_2 and annoyance was heterogeneous among cities (p for heterogeneity <0.001).

Conclusions: Annoyance is associated with home outdoor air pollution but with a different strength by city. This indicates that annoyance is not a valid surrogate for air pollution exposure. Nevertheless, it may be a useful measure of perceived ambient air quality and could be considered a complementary tool for health surveillance.

The assessment of individuals' exposure to traffic-related air pollution is complicated. Personal or home outdoor measurements are not easily feasible in large epidemiological studies and tend to be very expensive. Modelling presents an alternative; but adequate information is not always available on source emissions or from environmental measurements.[1] It has been suggested that annoyance caused by air pollution reported through a questionnaire could be used as an indicator of exposure to air pollution.[2 3] Several studies have shown a moderate to good association between central levels of air pollution and annoyance but they also concluded that personal characteristics were stronger determinants than the actual levels of air pollution.[2–8] Few studies have assessed the association between nitrogen dioxide (NO_2) exposure at the individual level and annoyance caused by air pollution. NO_2 is widely used as a marker of exposure to traffic-related pollutants. Compared with other pollutants of interest, such as particulate matter of various sizes, it is far easier to measure NO_2 at many locations throughout a city. Such measurements combined with modelling approaches are frequently used to characterise spatial gradients of traffic-related pollution. Oglesby *et al*[3] suggested that annoyance could not replace home-based measurements, as annoyance was strongly influenced by personal factors and they also suggested that even adjusting for all the personal determinants would not be enough as they found interactions between NO_2 and individuals' variables. Rotko *et al*[5] did not find an association between home outdoor NO_2 and annoyance caused by air pollution while at home when doing the analysis at an individual level; they only found an association at the population level. In a previous study, we showed the determinants of annoyance in the European Community Respiratory Health Survey II (ECRHSII) population and we found a moderate association between annoyance and central measurements of particulate matter up to 2.5 microns in diameter and its sulphur content, although heterogeneous across centres.[4] Annoyance is assessed for the local environment around the house, which is not captured by centrally measured background pollutants. At that time home outdoor measurements of air pollution were available in a subgroup only. We have now linked modelled NO_2 home outdoor concentrations for the residence of the majority of subjects. This allows us to assess the association between air pollution and annoyance caused by air pollution, at the individual level in a larger population.

The objective of this study was to assess the association between reported annoyance caused by air pollution and home outdoor levels of NO_2 in 20 cities from 10 countries and investigate the geographical homogeneity thereof.

MATERIALS AND METHODS

Study population

The European Community Respiratory Health Survey was carried out in 28 urban centres in 11 European countries. It was first conducted in 1991–3 and repeated in 1999–2001. Centres were chosen on the basis of pre-existing administration boundaries, their size and the availability of sampling frames. Subjects were randomly selected from the populations aged 20–44 years in 1991–3. A subsample of symptomatic subjects was also recruited. The details of this project study are described elsewhere.[9 10]

Table 1 Description of outdoor NO_2 (median and interquantile range) and description of annoyance (mean and percentage of highly annoyed), per city

Centre*	N: With modelled NO_2	N: With measured NO_2	NO_2† in percentiles: p25	p50	p75	Annoyance: Mean	% ≥6
Reykjavik (IC)	0	82	7.30	12.25	19.20	0.70	1
Umeå (SW)	151	117	4.88	9.75	12.47	1.63	9
Upssala (SW)	487	0	11.27	15.45	19.75	1.04	5
Tartu (ES)	0	37	19.30	22.20	26.20	2.54	11
Goteborg (SW)	318	0	23.41	26.67	28.74	1.04	4
Norwich (UK)	223	13	22.50	25.40	27.05	1.86	10
Ipswich (UK)	232	12	24.90	26.10	28.00	2.95	23
Antwerp (BE)	532	0	22.99	27.83	32.93	3.36	24
Erfurt (GE)	83	0	19.61	24.48	25.84	2.90	18
Paris (FR)	424	0	49.05	50.46	52.57	3.34	25
Basel (SZ)	0	88	29.23	34.35	38.75	3.57	30
Grenoble (FR)	382	0	25.41	30.80	31.45	2.69	16
Verona (IT)	205	0	23.87	27.54	29.43	2.84	22
Pavia (IT)	192	0	15.36	19.31	23.72	1.84	13
Torino (IT)	73	0	35.90	38.33	40.59	3.62	29
Oviedo (SP)	139	0	24.13	30.48	32.09	2.55	17
Galdakao (SP)	359	0	19.89	25.50	33.02	2.61	16
Barcelona (SP)	255	1	53.45	57.32	59.19	3.61	25
Albacete (SP)	140	4	28.32	29.75	31.81	3.35	24
Huelva (SP)	204	0	29.68	33.42	33.70	4.38	40
Total	4399	354	19.89	27.10	32.93	2.48	16.73

NO_2, nitrogen dioxide; BE, Belgium; ES, Estonia; FR, France; GE, Germany; IC, Iceland; IT, Italy; SP, Spain; SW, Sweden; SZ, Switzerland; UK, United Kingdom.
*Cities are ordered from north to south.
†Including 4399 modelled plus 354 measured home outdoor NO_2 levels.

This analysis was based on the second survey, including all the subjects from the random samples with modelled home outdoor NO_2 who had answered the annoyance question. Less than 3% of the subjects included in the analysis (141 subjects out of 4898) did not respond to the annoyance question. When the modelled NO_2 was not available, home outdoor measurements were used if obtained. A total of 4753 (4399 with modelled NO_2 and 354 with measured home outdoor NO_2) subjects in 20 cities in 10 countries were included. Sample size varied by centre from 37 in Tartu (Estonia) to 532 in Antwerp (Belgium). Ethical approval was obtained for each centre from the appropriate institutional or regional ethics committee, and written consent was obtained from each participant.

Description of variables

Annoyance caused by air pollution was self-reported on an 11-point scale (0, no disturbance at all; 10, intolerable disturbance) through the following question: ''How much are you annoyed by outdoor air pollution (from traffic, industry, etc) if you keep the windows open?''. The other variables used in this analysis were sex, age, night shortness of breath, chronic phlegm, ever rhinitis, socioeconomic status (based on occupation), smoking (never, ex, current) and exposure to environmental tobacco smoke. Self-reported traffic was also associated with annoyance but it was not used in this analysis because it is closely related to NO_2.

Modelled NO_2 measurements from APMoSPHERE

Modelled NO_2 was derived from the European Union (EU)-funded APMoSPHERE (Air Pollution Modelling for Support to Policy on Health and Environmental Risks in Europe). NO_2 has been widely used as a marker for traffic-related air pollution. As part of APMoSPHERE 1 km resolution emission maps of several pollutants, including NO_2, were developed for the then member states (EU15). Estimates were obtained by disaggregating national emissions estimates, categorised by sources of air pollution (SNAP categories), to the 1 km level on the basis of relevant proxies (eg, population density, road distribution, land cover).[11] Modelling of NO_2 concentrations was then done using focal sum techniques, in a geographical information system, to

Table 2 Ratio of mean annoyance scores from negative binomial regression

	Crude: Ratio of mean score (95% CI)	Adjusted by centre: Ratio of mean score (95% CI)	Adjusted*: Ratio of mean score (95% CI)
NO_2 increase per 10 $\mu g.m^{-3}$†	1.29 (1.25 to 1.33)	1.27 (1.21 to 1.35)	1.26 (1.19 to 1.34)
NO_2 in quartiles‡	1.58 (1.42 to 1.76)	1.38 (1.21 to 1.58)	1.38 (1.20 to 1.60)
	2.06 (1.85 to 2.29)	1.60 (1.40 to 1.84)	1.53 (1.30 to 1.78)
	2.53 (2.27 to 2.81)	1.84 (1.58 to 2.15)	1.85 (1.55 to 2.19)
NO_2 >27 $\mu g.m^{-3}$§	1.78 (1.65 to 1.91)	1.32 (1.20 to 1.45)	1.29 (1.16 to 1.44)

NO_2, nitrogen dioxide.
*Sex, socioeconomic status, night shortness of breath, chronic phlegm, rhinitis, smoking, passive smoking, centre.
†Continuous.
‡Categorical, the reference is the lowest quartile.
§Dichotomous, below and above the median for measured plus modelled home outdoor NO_2 levels.

relate emissions within concentric zones around each monitoring site to the monitored concentrations. Models were developed using monitoring data from 714 background sites for 2001, drawn from the EU Airbase database.[11] Validation was conducted by comparing predictions with observations for a separate set of 228 sites ($r^2 = 0.60$).

When modelled NO_2 estimates could not be provided, home outdoor measurements were used if available. That was the case for three cities that were/are not in the European Community (Reykjavik, Tartu and Basel, resulting in 207 subjects), for the subjects in Umeå who did not live in the city centre and were not geocoded for local reasons (117 subjects) and for some cases in the United Kingdom (25 subjects) and Spain (five subjects) for whom the address was not clear or was missing.

Home outdoor NO_2 measurements

Measurements of NO_2 as a marker for local tail pipe emissions were made at the homes of a subset of participants. At this individual level, outdoor (at the kitchen, or bedroom when kitchen was not available, window) and kitchen indoor NO_2 concentrations were collected during a 14-day period in 16 centres during 2001, involving approximately 2050 households of subjects who did not move house during the follow-up. After approximately 6 months this procedure was repeated in 40% of the households. Values below limits of detection were set at half the detection limit (0.34 $\mu g.m^{-3}$) and values above 150 (maximum 180) $\mu g.m^{-3}$ were set to 150 $\mu g.m^{-3}$. The passive samplers (Passam AG, Switzerland) were analysed in a central laboratory. For subjects with two measurements the mean of the two was calculated. Home outdoor NO_2 measurements were used in this analysis when modelled NO_2 measurements were not available.

Statistical analysis

Negative binomial regression was used to assess the association between annoyance and NO_2. The multivariate model used was the same as that previously applied to analyse annoyance for this population.[4] The variables included in the original model were sex, socioeconomic status, night shortness of breath, chronic phlegm, rhinitis, smoking status, exposure to environmental tobacco smoke and self-reported car and heavy vehicle traffic. Self-reported traffic was not, however, included in the model used here, as traffic is closely related to NO_2 (and data on road traffic emissions are employed in the APMoSPHERE models). Annoyance and the other variables associated with it in the multivariate model were tested to see if subjects with NO_2 measurements were different from those without measurements from the ECRHSII population. The Wilcoxon–Mann–Whitney test was used for the annoyance score and the χ^2 test for categorical variables. NO_2 was analysed as a continuous variable, in quartiles and dichotomously (below and above the median). The results are expressed as ratios of the mean annoyance scores. Effect estimates were derived for each centre and area and heterogeneity across cities was examined by using standard methods for random effects meta-analysis. To help measure how well the estimates capture the variability of the annoyance score, we used the pseudo R^2 given by the software, which is analogous to the R^2 of the ordinary logistic regressions. The pseudo R^2 presented here was the inverse of the likelihood of the full model over the likelihood of the model including only the constant. The analysis was made using Stata 8 (Stata Corp, College Station, Texas, USA). The criterion for statistical significance was set at a p value of less than 0.05.

RESULTS

Central medians of NO_2 levels varied from 9.75 $\mu g.m^{-3}$ in Umeå (Sweden) to 57.32 $\mu g.m^{-3}$ in Barcelona (Spain). In general, northern centres had lower levels of NO_2. In table 1, centres are ordered from north to south and data show the distribution of NO_2 home outdoor level means per centre.

The distribution of annoyance per centre is reported in table 1 and the means ranked from 0.7 in Reykjavik (Iceland) to 4.38 in Huelva (Spain). The percentage of subjects highly annoyed (6 or more on the scale) varied from one in Reykjavik to 40 in Huelva. A north to south trend in reported annoyance was observed.

The association between NO_2 and annoyance was positive and significant, disregarding the NO_2 categorisation or the level of adjustment. When categorising the NO_2, the estimates increased in accordance with NO_2 quartiles (table 2).

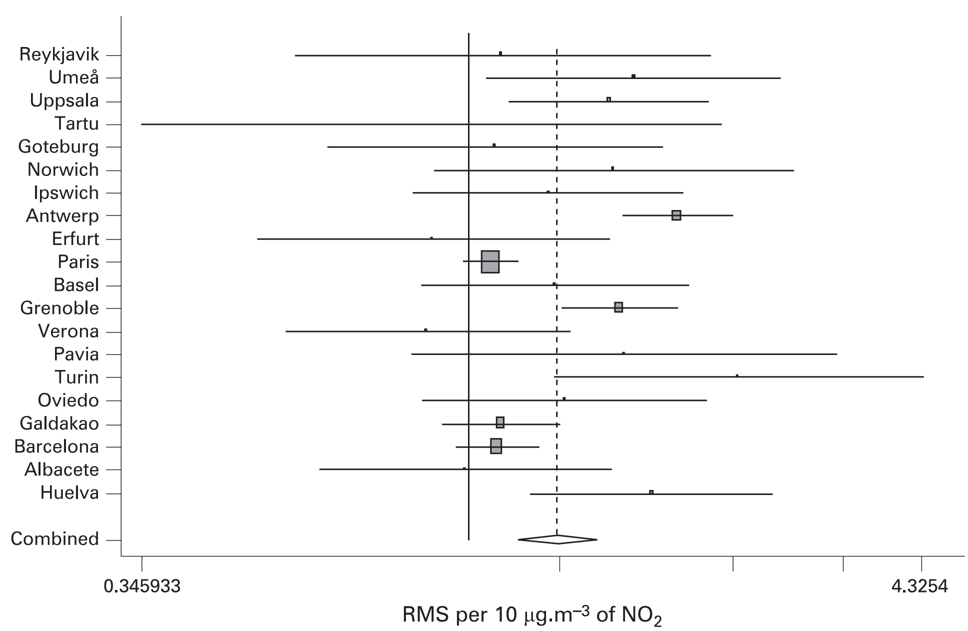

Figure 1 Adjusted ratios of mean annoyance score (RMS) comparing the effect of nitrogen dioxide (NO_2) per centre.

Table 3 Ratio of mean annoyance scores from negative binomial regression by each centre

	Crude*		Adjusted***†	
	Ratio of mean score (95% CI)	R^2‡	Ratio of mean score (95% CI)	R^2‡
Reykjavik	1.23 (0.66 to 2.29)	0.003	1.11 (0.57 to 2.18)	0.062
Umeå	1.73 (1.14 to 2.64)*	0.007	1.70 (1.06 to 2.73)*	0.026
Uppsala	1.57 (1.16 to 2.13)*	0.007	1.57 (1.14 to 2.17)*	0.027
Tartu	1.27 (0.68 to 2.38)	0.004	0.88 (0.35 to 2.25)**	0.104
Goteburg	1.14 (0.67 to 1.94)	0.000	1.09 (0.63 to 1.88)	0.015
Norwich	1.78 (1.11 to 2.84)*	0.007	1.60 (0.89 to 2.85)	0.032
Ipswich	1.25 (0.85 to 1.84)	0.001	1.29 (0.83 to 1.99)	0.006
Antwerp	1.89 (1.61 to 2.23)*	0.024	1.96 (1.63 to 2.35)*	0.035
Erfurt	0.88 (0.56 to 1.38)	0.001	0.89 (0.50 to 1.58)**	0.037
Paris	1.08 (0.99 to 1.18)**	0.002	1.08 (0.98 to 1.18)	0.014
Basel	1.16 (0.83 to 1.60)	0.002	1.32 (0.86 to 2.03)	0.020
Grenoble	1.74 (1.45 to 2.08)*	0.021	1.62 (1.35 to 1.96)*	0.030
Verona	1.03 (0.69 to 1.55)	0.000	0.87 (0.55 to 1.39)**	0.016
Pavia	1.60 (0.93 to 2.75)**	0.004	1.65 (0.83 to 3.28)	0.024
Torino	1.55 (0.83 to 2.88)	0.005	2.38 (1.31 to 4.33)*	0.108
Oviedo	1.19 (0.80 to 1.76)	0.001	1.37 (0.86 to 2.16)	0.023
Galdakao	1.16 (0.99 to 1.35)**	0.002	1.11 (0.91 to 1.34)	0.007
Barcelona	1.11 (0.98 to 1.26)	0.002	1.10 (0.96 to 1.26)	0.016
Albacete	1.07 (0.70 to 1.62)	0.000	0.99 (0.61 to 1.59)**	0.015
Huelva	1.58 (1.16 to 2.15)*	0.008	1.80 (1.23 to 2.65)*	0.036
All fixed	1.26 (1.19 to 1.32)*	0.013	1.24 (1.18 to 1.32)*	0.034
All random	1.32 (1.18 to 1.49)*	NA	1.33 (1.17 to 1.52)*	NA

*$p<0.05$; **$p<0.10$; ***$p<0.001$ for heterogeneity.
†Sex, socioeconomic status, night shortness of breath, chronic phlegm, rhinitis, smoking, passive smoking, centre.
‡Pseudo R^2 of the whole model.

Figure 1 shows the centre-specific adjusted estimates. The p value for heterogeneity was below 0.001. Table 3 shows the specific crude and adjusted estimates and the pseudo R2 of each model for each centre. For the adjusted analysis the association was positive and significant in Umeå, Uppsala, Antwerp, Grenoble, Torino and Huelva; positive but not significant in Reykjavik, Goteborg, Norwich, Ipswich, Paris, Basel, Pavia, Oviedo, Galdakao and Barcelona and negative but not significant in Tartu, Erfurt, Verona and Albacete. The general pseudo R^2 for the crude model was 0.13 and the pseudo R^2 distribution within cities varied from 0 to 0.024 for the crude model and from 0.006 to 0.104 in the adjusted model.

The association between annoyance and NO_2 stratified by gender and by respiratory symptoms is presented in table 4. All the subgroups showed a similar association and in all cases the pseudo R^2 was low, approximately 0.03. Stratifying by atopy gave similar results; the pseudo R^2 being 0.04 in atopic and 0.03 in non-atopic individuals.

DISCUSSION

Annoyance caused by air pollution was associated with home outdoor NO_2 measurements; nevertheless this association was different among cities. The estimates were very weak even in the centres with the strongest associations and were even negative in some cities. No clear geographical pattern could be observed. No specific subgroup of subjects who could better predict NO_2 with annoyance was found.

One of the strengths of this study was the large number of participating cities across Europe, allowing us to compare the heterogeneity of associations between NO_2 and annoyance across different European countries. Another advantage was that it included measurements of NO_2 estimated (or measured) at the place of residence, thus allowing the association with annoyance to be analysed at the individual level. Although NO_2 per se may not cause annoyance, it is a widely used surrogate of traffic-related pollutants and thus is expected to correlate with traffic emissions that may be more easily identified as a bad smell. For annoyance caused by air pollution, to our knowledge, only three previous studies have used individual-level air pollution concentrations.[3 5 7]

An issue that has been raised previously about the association between annoyance caused by air pollution and air pollution is that the question itself has limitations in its phrasing. On the one hand, it concerns annoyance caused by outdoor air

Table 4 Ratio of mean annoyance scores from negative binomial regression stratified

	All		For women		For men		Without any respiratory symptoms		With any respiratory symptom	
	Ratio of mean score (95% CI)	R^2†	Ratio of mean score (95% CI)	R^2†	Ratio of mean score (95% CI)	R^2†	Ratio of mean score (95% CI)	R^2†	Ratio of mean score (95% CI)	R^2†
Crude	1.29 (1.25 to 1.33)	0.01	1.28 (1.23 to 1.34)	0.01	1.30 (1.24 to 1.37)	0.01	1.30 (1.22 to 1.38)	0.01	1.28 (1.23 to 1.33)	0.01
Adjusted per centre	1.27 (1.21 to 1.35)	0.03	1.32 (1.23 to 1.42)	0.03	1.20 (1.11 to 1.30)	0.03	1.38 (1.24 to 1.53)	0.03	1.23 (1.15 to 1.31)	0.03
Fully adjusted*	1.26 (1.19 to 1.34)	0.03	1.31 (1.20 to 1.42)	0.04	1.22 (1.11 to 1.33)	0.04	1.41 (1.25 to 1.58)	0.03	1.21 (1.13 to 1.29)	0.03

*Sex, socioeconomic status, night shortness of breath, chronic phlegm, rhinitis, smoking, passive smoking, centre.
†Pseudo R^2 of the whole model.

pollution while indoors; this is likely to be influenced by the frequency with which the individuals open their windows, as well as the proportion of time spent indoors and general ventilation conditions. Assuming that individuals in colder (northern) countries are less likely to open their windows, we would expect weaker associations in northern countries. This was, however, not the case: the association between annoyance and air pollution showed no clear geographical pattern. The estimates, as well as the pseudo R^2, for each centre were instead very heterogeneous. It is also important to note that the inclusion in the multivariate model of the variable "Do you sleep with the window open in winter?", as well as the variable assessing the frequency of such events, did not alter the estimate of the association between annoyance and NO_2. In stratified analyses, the estimate was similar in subjects sleeping with the window open to those who do not, and even tended to be slightly smaller in the former. To sleep with the window open was associated with annoyance only in the crude model; once centre was added into the model, the association disappeared. The season of the interview was not associated with annoyance, nor with the association between annoyance and NO_2.

Another weakness of this study is that the subsample for whom NO_2 values were available was not the same as that without them. Subjects with NO_2 concentrations available tended to be more annoyed by air pollution. They also included more women and more people in formal employment (as opposed to others such as housewives or students), had more rhinitis, were less likely to be current smokers and reported more traffic than the subjects without NO_2 values. The reasons for these discrepancies are not clear, because a high proportion (70%) of participants in the random sample of ECRHSII had NO_2 values. The main determinant of exposure estimation was the ability to geocode the address, which in principle has nothing to do directly with the personal characteristics of the subjects. There were, however, possible biases in Umeå and Goteborg, where only participants living in the city centre could be geocoded.

Most of the studies investigating the association between annoyance and air pollution have found a correlation between both, using central, personal modelled and/or individual concentrations of pollutants. They have also usually concluded that personal characteristics also play a big role in the rating of annoyance. To our knowledge, however, no previous studies have compared associations between countries.

Forsberg *et al*,[2] for example, showed an association between annoyance caused by air pollution and central NO_2 concentrations. The correlation coefficient between the percentage of subjects reporting annoyance per city or town and the 6-month average NO_2 was approximately 0.60. They found a better correlation for subjects living in urban areas than for those living in residential areas.[2] Williams and Bird[6] showed that the perception of air pollution was not a reliable indicator of the actual levels when using the measurements from the nearest monitoring station in Greater London. They did not compare among different cities but they showed that inside the same city, subjects living in urban areas were more disturbed than subjects living in suburban areas. Klaeboe *et al*[7] found an association between environmental annoyance and a 3 months mean of modelled NO_2 in Oslo. Subjects tended to have more complaints or higher levels of annoyance when the levels of NO_2 were higher.[7] Oglesby *et al*[3] found a significant association between high annoyance caused by air pollution and estimated home outdoor NO_2 in eight Swiss cities. The association was not, however, significant when they used the annoyance score. The crude correlation between annoyance score and estimated home outdoor NO_2 was $r = 0.36$ and explained 7.5% of the annoyance variance. They also suggested that subjects could rate annoyance differently from one area to another within the same country.[3] Rotko *et al*[5] found a very high correlation between annoyance caused by air pollution in traffic and the home outdoor NO_2 concentration when aggregating the results by city ($r = 0.99$). When assessing the association individually, it was significant but the crude model only explained 13% of the annoyance variance. They had individual level NO_2 measurements for four cities in Europe but they did not compare between the cities.[5] In a previous publication,[4] we assessed the association between annoyance caused by air pollution and air pollution characterised at one central monitor instead of the residential location. We found a moderate association that was heterogeneous among centres.[4] Now, in this study we show how the relation between annoyance and air pollution also differed by geographical areas even using individual determinations. The association is heterogeneous and the levels of NO_2 explained very little of the annoyance variance at the individual level, as reported previously.

Even if home outdoor NO_2 and annoyance caused by air pollution are associated, we do not recommend the use of annoyance as a surrogate for personal exposure to traffic-related air pollution. The general pseudo R^2 for the crude model was low and the pseudo R^2 distribution within cities varied. Only a small part of the NO_2 variation can thus be predicted on the basis of annoyance. The correlation is only partly explained by the levels of the pollutants and the personal characteristics. We were not able to identify a subgroup of subjects who would better predict the NO_2 level in comparison with the total population, although we selected women and/or subjects with respiratory symptoms in whom one could plausibly argue that those subjects tended to be more annoyed by air pollution.[4] Another reason why we do not recommend the use of annoyance as an air pollution indicator is its heterogeneity. The estimates varied from negative to positive association without any discernable geographical pattern. To interpret a pooled estimate would be incorrect.

The fact that the association between annoyance and NO_2 varies from city to city suggests a sociocultural influence. The importance of personal, social and cultural factors in influencing risk perception has long been well established.[12] Bickerstaff[13] explained how social and cultural factors could influence the perception of air pollution. The main conclusion was probably that the perception of risk takes into account numerous factors including social, political and cultural ones and that there is not a set of variables that could predict the risk perception at a group level. Olofsson and Ohman[14] showed that personal characteristics, including political affiliation or education, could predict environmental concern but the addition of general beliefs, such as beliefs about science or a view of nature, increased predictability. They also showed that the individual factors related to environmental concern were not the same and did not have the same predictive power between the two geographical areas they studied (north America versus Scandinavia). Dietz *et al*[15] investigated whether individual characteristics and/or beliefs could explain their environmental willingness to act. They found no clear association and that environmental participation was not predictable. Annoyance is thus subjective, and not all the annoyance can be explained by measurable variables. Subjectivity does not, however, take away its importance, as it reflects the subjects' feelings. Also it has

What this paper adds

- It has been suggested that annoyance caused by air pollution reported through a questionnaire could be used as an indicator of exposure to air pollution. Several studies have shown a moderate to good association between central levels of air pollution. The objective of this study was to assess the association between reported annoyance caused by air pollution and home outdoor levels of NO_2, a marker for traffic-related pollution, in 20 cities from 10 countries and investigate the geographical homogeneity thereof.
- Annoyance caused by air pollution was associated with home outdoor NO_2 measurements; nevertheless this association was heterogeneous among cities. No specific subgroup of subjects who could better predict NO_2 with annoyance was found. Whereas this and other studies ultimately confirm that annoyance is not a valid maker of air pollution exposure, it is important in its own right as it integrates perception, feelings of security and health problems.

been suggested that annoyance per se could have health effects. Individuals are aware of health effects of air pollution and are concerned about it, even when the levels are in accordance with the guidelines.[16 17] Lercher *et al*[8] found an association between annoyance and respiratory symptoms not explained by air pollution concentrations and suggested that the perception of polluted air could trigger annoyance and symptoms even when air pollution levels are below the guidelines. It has also been suggested that a negative impression of the general environment of the neighbourhood was associated with a lower health quality.[18 19]

Policy makers might take into account the annoyance caused by air pollution as a direct outcome of interest. Although this and other studies ultimately confirm that annoyance is not a valid maker of air pollution exposure, it is important in its own right as it integrates individual perception, feelings of security and health problems. It may also influence trust in government and the regulatory authorities.[20] Its standardised measurement is simple and it could easily be added to environmental monitoring and health tracking surveys.

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