People can detect poor air quality well below guideline concentrations: a prevalence study of annoyance reactions and air pollution from traffic

Bertil Forsberg, Nils Stjernberg, Stig Wall

Abstract

Objectives—Motor vehicle exhaust fumes are the main source of atmospheric pollution in cities in industrialized countries. They cause respiratory disease and annoy people exposed to them. The relation between ambient exposure to air pollution mainly from motor vehicles and annoyance reactions in a general population was assessed. Also, the importance of factors such as age, sex, respiratory disease, access to the use of a car, and smoking habits on the reporting of these reactions was studied.

Methods—A postal questionnaire was sent out in 55 urban areas in Sweden that had nearly identical air quality monitoring stations of the urban air monitoring network. From each area, 150 people aged 16–70 were randomly selected. The questionnaire contained questions on perception of air quality as well as a question on how often exhaust fumes were annoying.

Results—Six-monthly nitrogen dioxide concentrations correlated consistently with the prevalence of reported annoyance related to air pollution and traffic exhaust fumes. Black smoke and sulphur dioxide had no significant effects. The frequency of reporting annoyance reactions was higher among people with asthma, women, and people with lack of access to a car.

Conclusions—In this study town dwellers could detect poor air quality at concentrations well below current guidelines for outdoor air pollution. This suggests that questionnaire studies have a place in monitoring air quality.

(Occup Environ Med 1997;54:44-48)

Keywords: air pollution; traffic; annoyance

Vehicle exhausts are the main source of air pollution in most cities in industrialized countries. They may cause respiratory disease, and more often, result in annoyance reactions including physical irritation. Despite the large populations exposed to traffic pollution sufficient to cause irritation, few studies have been published on the quantitative relations between the exposure to traffic pollution and the prevalence of annoyance reactions.

Research in this field was built on social survey techniques and compared mostly qualitatively different environments.4 We think that many local studies have not been published as general conclusions could not be drawn from them because they lacked objective measurements of air quality. When measured, exposure-response relations could be used for defining guidelines on good air quality and for predictions of benefits from decreased air pollution.

A Swedish study of car exhaust and annoyance showed that people with a negative attitude to traffic, women, and those with symptoms of respiratory sensitivity (such as asthma) are more likely to be annoyed by exhaust fumes. However, multivariate analysis was not used in this study and women were overrepresented in both the symptomatic risk group and the group with negative attitudes. All factors studied should be analysed simultaneously to avoid confounding, even if only a few factors are studied.

Concentrations of nitrogen dioxide in Swedish towns and cities are highest in winter and result from emissions from motor vehicles and adverse dispersive conditions. However, concentrations are low compared with those reported in studies of health effects. The aim of this study was to assess the relation between a moderate range of concentrations of pollutants in ambient air and the presence of annoyance reactions in a general population. The importance of individual characteristics such as age, sex, presence of respiratory problems, access to a car, and smoking habits was studied as well as air quality.

Methods

QUESTIONNAIRE INFORMATION

A total of 8250 subjects were randomly selected from among people living in the vicinity of 55 urban air quality monitoring stations in towns and cities throughout Sweden. From each area 150 subjects aged 16–70 were chosen. However, some had to be excluded because they were found to live outside the chosen areas. Therefore, the total sample population comprised 8060 subjects.

A postal questionnaire was sent early in March 1990 with two reminders sent about two and four weeks later. The questionnaire was presented as a broad study of the local environment, work environment, environmental annoyance, and health. It also included questions on occupation, place of birth, smoking habits, commuting to work or school, access to a car, and household members.

Three questions were concerned with how often the outdoor air during winter in the area...
where the subjects lived was perceived as being irritant, smelly, and dirty or sooty. Three additional questions dealt with similar aspects of the outdoor air in the town or city centre. One question dealt with how often traffic exhaust fumes where the subjects lived were considered to be annoying. Responses were never or almost never, sometimes or periodically, or daily or almost daily. A response of daily or almost daily was considered to indicate serious annoyance. The response rate was 76% (6109 out of 8060) after the subjects who did not reside at their postal addresses had been excluded.

INFORMATION ON AIR QUALITY

The study areas were selected so that the air quality monitoring station was centrally located. Thus only rarely was any part of the study area more than 700 m from a station. The Swedish urban air monitoring network is run by the Swedish Environmental Research Institute (IVL) accredited laboratory in collaboration with the local environmental health offices. Locations were chosen so that the results would not be dominated by single sources, and measurements were usually made 5–6 m above the ground in streets in city centres accessible only to pedestrians, or in open areas without specific sources of pollution. The average daily concentrations of black smoke (modified OECD), sulphur dioxide (impinger method), and nitrogen dioxide (impregnated glass fibre filter) were measured each day from October 1989 to March 1990 (a six month period). Motor vehicles were the main source of air pollution in all areas.

**ANALYSIS**

Firstly, a descriptive analysis was made by correlating the prevalences of annoyance related to air pollution with the level of air pollution measured in each town. These data were also inspected with scattergrams. Adjustment for factors other than the level of air pollution was then made, with multiple logistic regression based on data from each person. The factors which were included were potential susceptibility factors—age (six categories), sex, and the presence of asthmatic symptoms, and questions related to individual exposure patterns—whether or not the subject had access to a car, if the home was next to an area with a high density of traffic, and the subject’s smoking habits (three categories). There was also a question on whether children lived at home. The models included an indicator variable for each town. The estimated $\beta$-coefficients for the towns, which represent the log odds of annoyance, were then analysed by multiple linear regression with the pollution indices as independent variables.

**Results**

**AIR POLLUTION**

Air pollution at all monitoring stations fell well below the World Health Organisation (WHO) air quality guidelines for Europe and Swedish air quality standards (table 1). The mean six-monthly averages were 19, 9, and $6 \mu g/m^3$ for nitrogen dioxide, black smoke, and sulphur dioxide, respectively, and the upper quartile limits were 22, 10, and $8 \mu g/m^3$. The local six-monthly average for each of the three pollutants correlated strongly with the corresponding monthly ($r = 0.88–0.94$) and daily maximum values ($r = 0.68–0.87$). There was also a significant correlation between the six-monthly average nitrogen dioxide and black smoke ($r = 0.55, P < 0.01$).

**PREVALENCES AND CORRELATIONS**

Table 2 shows the proportion of subjects expressing daily or almost daily annoyance and the correlation coefficients for these annoyance prevalences with the air pollution measures. No measure of black smoke correlated significantly with any of the annoyance prevalences. Black smoke has therefore not been included in the table.

<table>
<thead>
<tr>
<th>Annoyance</th>
<th>Prevalence (%)</th>
<th>Correlation coefficients ($r$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Maximum</td>
</tr>
<tr>
<td>Outdoor air in the town centre daily or almost daily:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smelly</td>
<td>8.6</td>
<td>28.4</td>
</tr>
<tr>
<td>Irritant</td>
<td>7.7</td>
<td>17.6</td>
</tr>
<tr>
<td>Diry or sooty</td>
<td>11.5</td>
<td>26.5</td>
</tr>
<tr>
<td>Outdoor air in the residential area daily or almost daily:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smelly</td>
<td>6.1</td>
<td>18.1</td>
</tr>
<tr>
<td>Irritant</td>
<td>4.8</td>
<td>13.9</td>
</tr>
<tr>
<td>Diry or sooty</td>
<td>10.1</td>
<td>23.8</td>
</tr>
<tr>
<td>Annoyed by traffic exhaust fumes in the residential area daily or almost daily</td>
<td>16.8</td>
<td>34.6</td>
</tr>
</tbody>
</table>

*P value < 0.05; **P value < 0.01. 6-MA = six-monthly average; MM = monthly maximum; DM = daily maximum.
Traffic exhaust fumes where the subjects lived were most often considered to be annoying. The local prevalence ranged from 2% to 35% (mean 17%).

A greater proportion of subjects were troubled in various ways by the air in the town or city centre than by the air in their residential area. More found the outdoor air frequently dirty or sooty than smelly or irritating. The local prevalences in the city centres ranged from 1% to 26% (dirty or sooty), 0% to 28% (smelly), and 0% to 18% (irritating). The highest prevalences of smells were found in towns with nearby industries, such as pulp mills, that emitted malodorous air pollutants.

The strongest correlations between measures of air pollution and prevalence of annoyed subjects by town or city was found between the six-monthly average nitrogen dioxide concentration and the prevalence of subjects who daily or almost daily found the air during winter in the town or city centres \((r = 0.66)\) or residential areas \((r = 0.65)\) to be irritating. A direct age standardisation with six age classes had little effect on the correlation coefficients; the coefficients for the two correlations already mentioned were 0.64 and 0.65, respectively. The figure shows the plot of the proportions of subjects (age standardised) who reported that they daily or almost daily found the air in the area where they lived irritating against the concentration of nitrogen dioxide at the central monitoring station. There was no indication of a threshold level in the examined plots.

For all annoyance variables, the six-monthly average concentration of nitrogen dioxide gave better correlations than monthly maximum or daily maximum concentrations. A multiple linear regression of annoyance prevalences on the six-monthly averages for concentrations of nitrogen dioxide, sulphur dioxide, and black smoke showed that the annoyance prevalences were significantly related only to the average concentrations of nitrogen dioxide. The age standardised prevalence of reporting outdoor air as being irritating every, or almost every, day in the town or city centres and the residential areas respectively, gave regression coefficients of 0.64 (95% CI 0.39–0.88) and 0.43 (95% CI 0.28–0.59) for nitrogen dioxide concentrations.

### ADJUSTED ASSOCIATIONS WITH AIR POLLUTION

When the \(\beta\)-coefficients for the towns from the logistic regression were analysed with multiple linear regression, only nitrogen dioxide was a significant determinant, and the results were consistent in all seven models (table 3). The non-significant relations with sulphur dioxide and black smoke are not shown. The association with nitrogen dioxide was greater for the annoyance questions which dealt with different aspects of air pollution in the town or city centre than it was for questions on the outdoor air in the area in which the subject lived. The effect was strongest for reporting the outdoor air in the city or town centre as smelly or irritating. When the analyses were stratified for sex, there were some differences in the coefficients between men and women, but they were not consistent for the different annoyance variables.

### INDIVIDUAL DETERMINANTS

The importance of individual characteristics was found in the logistic regression models. The results were similar for the different annoyance variables. Table 4 shows the results for the questions on the outdoor air being irritating. The frequency of reporting that the air was irritating was lowest in the youngest group, aged 16–24 years. Otherwise there was no age related trend. Women showed a significantly higher prevalence than men, the odds ratios being 1.4 and 1.5 for the two questions respectively.

Asthma, which was reported by 8% of the...
respondents, was a strong risk factor, with
odds ratios of 3·6 and 3·9, respectively for the
two questions. Lack of access to a car was also
a significant risk factor, but living in a home in
an area of heavy traffic was a significant risk
only in the model for the air in the town or city
centre. Smokers who lived at home were not significant risk factors for
reporting that the outdoor air was irritating.

Discussion
When asked in what manner subjects found
the outdoor air annoying, more people consid-
ered that the air was more often dirty or sooty
than smelly or irritating. Similar results were
reported from London, UK, and the authors
suggest that smoke and concentrations of total
suspended particles may be better indicators of
the nuisance effect than other measures of
pollutants.4 In 21 highly polluted census tracts
in Birmingham, Alabama,5 dustfall had a more
significant association with public opinion
about air pollution (r = 0·80) than total sus-
pended particles (r = 0·54) or average con-
centrations of nitrogen dioxide, which were
not significantly correlated with the public
opinion. A review of British surveys of the
public’s response to traffic pollution carried
out in the 1970s also found that the public
were most concerned about dirt and soiling
associated with road traffic.6 In this study
more people found the outdoor air dirty or
sooty than smelly or irritating. However, we
found that the local prevalence of annoyance
related to air pollution in 55 Swedish towns
and cities did not correlate significantly with
black smoke. The best correlations were found
with long term concentrations of nitrogen
dioxide.

Multivariate analyses showed that only
nitrogen dioxide was significant when sulphur
dioxide and black smoke were also included in
the models. Our results show this dose-
response relation for annoyance reactions in
town or city centres at mean six-monthly winter
half yearly concentrations of nitrogen dioxide
below 33 μg/m3.7 The current Swedish air qual-
ity standard for the six-monthly average con-
centration of nitrogen dioxide is 50 μg/m3.
The concentration of nitrogen dioxide at the
monitoring station may in this situation be
regarded as an indicator of the population’s
average exposure to air pollution related to
vehicle exhaust fumes which makes generalisa-
tions easier than results based on the often
used variants of traffic flow within certain dis-
tances.8

Information about the quantitative relation
between measured air quality and annoyance
reactions related to air pollution has been lack-
ing, although the importance of individual fac-
tors related to the reporting of annoyance in
different situations has been described.9

In epidemiological studies of acute respira-
tory effects of short term variations in air pollu-
tion, people with asthma have been shown to
be a susceptible group but whether or not this is
due to nitrogen dioxide has not been conclu-
sively proved.10 11 Human chamber studies
have generally shown effects on pulmonary
function only at concentrations of nitrogen
dioxide much higher than those reported in
epidemiological studies. Particles, together
with sulphur dioxide and ozone, are the most
obvious pollutants that worsen asthma, but in
Nordic countries, traffic is the major source of pollution, nitrogen dioxide has cor-
related significantly with hospital visits for
asthma,12 pulmonary function in people with
asthma13 and the prevalence of general symp-
toms.14 Our results confirm that subjects with
symptoms of asthma more often perceive the
outdoor air as irritating. Lack of access to a car
resulted in higher odds ratios. This could
mean that people forced to travel by walking
from home, perceive more the annoyance
from pollutants in the vicinity of their homes.
Their attitudes toward traffic pollution may
also be different from those who own cars.

In an earlier study Swedish women were
more annoyed than men by vehicle exhausts.3
Also in this study adjusted odds ratios for
women were higher than for men. It is possible
that non-measured acquired attributes associ-
ated with sex explain at least parts of the dif-
fERENCE between the sexes that remained after
our adjustment. Women have been shown to
be more environmentally concerned than men15 16 and this might affect awareness
and reporting. However, in a recent study after a
clinical examination the typical sex differences
in reporting sick building symptoms could not
be explained by women overreporting symp-
toms.17

In this large study of 55 samples from all
over Sweden, adjustment for various potential
confounding factors at the individual level did
not change the overall conclusion that the con-
centration of nitrogen dioxide is an important
predictor of annoyance reactions, in spite of
several individual characteristics being signifi-
cant risk factors. The effects of adjustments
for confounders may, however, differ from
study to study depending on the populations
included. As in all studies of ecological expo-
sure variables, there may be uncontrolled con-
founders of an ecological nature. As nitrogen
dioxide is predominantly generated locally
from motor vehicles in these cities, other traffic
related pollutants may contribute to the asso-
ciations we found. Our results show that people
can detect poor air quality related to motor
vehicles at long term concentrations well
below current guidelines, when assessed from
a postal questionnaire. This suggests that
questionnaire studies have a place in monitor-
ing air quality, and that improvements in air
quality will reduce the number of annoyed
people.

This study was supported by the Centre for Environmental
Research (CMF) in Umeå and the Swedish Environmental
Research Institute.

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B Forsberg, N Stjernberg and S Wall

*Occup Environ Med* 1997 54: 44-48
doi: 10.1136/oem.54.1.44

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