ORIGINAL ARTICLE

Air pollution and related respiratory diseases: the experience of a Local Health Authority in Liguria (North Italy)

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Key words

Air pollution • Motor traffic • Industrial emissions • Effects on health

Summary

Background. *Numerous epidemiological studies have shown that air pollution due to both industry and heavy traffic has short- and long-term effects on health. The study was carried out in an industrial area with heavy urban and motorway traffic in the Province of Genoa (Italy).*
Methods. *The study was carried out from June 2005 to July 2008. An epidemiologic study was conducted by monitoring an elementary/middle school situated in an area of recent industrial development and an elementary/middle school located in an area free from sources of industrial pollution. Furthermore, we conducted an investigation of workers in commercial premises situated in one area of heavy vehicular traffic. In the study areas, environmental monitoring campaigns were carried out in order to determine the association between indoor and outdoor pollution and respiratory disorders.*
Results and discussion. *The study did not bring to light any specific health problems attributable with certainty to industrial emissions. The impact of pollution caused by motor traffic proved to be greater than that due to industrial emissions. More exhaustive sampling campaigns should be implemented in order to quantify the effects of specific sources of emissions and to correlate these sources with pollutants (industry, urban traffic, motorway traffic).*

Introduction

Numerous epidemiological studies have shown that air pollution due to both industry and heavy traffic has short- and long-term effects on health [1-4]. Several investigations have found a correlation between some airborne pollutants, especially formaldehyde and benzene, and various types of tumor [5-9]. For this reason, in Italy concentrations of the main airborne pollutants are subject to control, in accordance with several legislative and ministerial decrees [10-12].
In order to assess the public health risk of exposure to air pollution and to implement appropriate preventive measures, it is essential to determine the type and concentration of pollutants present and to understand their dynamics in the atmosphere [13, 14].
Conducted in the Municipality of Busalla (Genoa), the present study was prompted by an increase in reports of discomfort and respiratory disorders among local residents. It was hypothesized that this increase might be due to the growth of industrial operations and vehicular traffic in the area. In order to determine the level of exposure of the resident population and to assess health risks, data on airborne pollutants were gathered. Specifically, sampling was carried out to determine the concentrations of formaldehyde (FOR) and volatile organic compounds (VOC): benzene (BZ), toluene (TO), ethyl benzene (ETBZ), meta-xylene (mXI), para-xylene (pXI) and ortho-xylene (oXI).

Materials and methods

The study was carried out from June 2005 to July 2008.
In the first phase, environmental and meteorological-climatic data (2003-2005) were analyzed in order to pick out sites for sampling and to ascertain the dispersion modalities of the pollutants. Industrial activities were also mapped and their emissions evaluated. The following industries are located in the area: oil refinery, production of pipes for the car industry, production of bituminous conglomerates, car-body workshops, carpentry factories, molding of plastic material, and typographies.

Epidemiologic study

An epidemiologic study was then conducted by monitoring an elementary/middle school situated in an area of recent industrial development (Busalla) and an elementary/middle school located in an area free from sources of industrial pollution (Mignanego) in January, February and March 2006. The parents of the schoolchildren were given an *ad hoc* questionnaire (Fig. 1). The questionnaire was specifically designed for the study, in order to

Fig. 1. Questionnaire for students.

Questionnaire for students

1. STUDENT CODE _____

2. Sex _____

3. Place of birth _____ date of birth _____

4. Resident in _____

5. Previous serious illnesses _____

6. Present or previous respiratory illnesses:

Illness	ascertained	on therapy
allergic rhinitis	☐	☐
respiratory allergy*	☐	☐
other allergy*	☐	☐
asthma	☐	☐
chronic bronchitis	☐	☐
pneumonia	☐	☐
irritability	☐	☐
headache	☐	☐

* specify _____

7. Journey to and from school mainly:

on foot ☐ by car ☐ school bus ☐ other _____

8. Do any cohabiting members of the family suffer from any of the following illnesses?

Illness	ascertained	on therapy
allergic rhinitis	☐	☐
respiratory allergy *	☐	☐
other allergy *	☐	☐
asthma	☐	☐
chronic bronchitis	☐	☐
pneumonia	☐	☐
irritability	☐	☐
headache	☐	☐

* specify _____

9. Do any cohabiting family members smoke?

	mother	father	grandparent	other (specify) _____	
Cigarettes smoked per day (about)	_____	_____	_____	_____	_____
Number of cigarettes smoked at home per day (about)	_____	_____	_____	_____	_____

10. Do you have: kitchen ☐ cooking area ☐ with: mains gas ☐ bottled gas ☐

heating: centralised in the whole building ☐ self-contained ☐ (mains gas ☐, kerosene ☐, wood ☐)

11. Do you have any of the following at home ?

printer ☐ fax machine ☐ photocopier ☐

INFORMED CONSENT TO THE HANDLING OF PERSONAL DATA

In accordance with the provisions of Article 13 of Legislative Decree 196/2003, the undersigned has been informed that the personal data recorded on this form will be used exclusively for the observational epidemiological study regarding the monitoring of formaldehyde, volatile organic compounds (benzene, I.P.A., etc.) and particulates within the framework of the project "Air quality and correlated illnesses in Busalla".

The Genoese Local Health Authority (A.S.L. 3) will be nominally responsible for the conservation and handling of data. The data will be kept at the head office of the Hygiene and Public Health Operational Unit, Zone 3 Genoa. Dr. Rita Tatarek will be responsible for data handling. Data handling will also be carried out by Dr. Miria Bosi and Dr. Valerio Tofanelli.

Having been provided with the necessary information, and being aware that the data to be handled are sensitive and, in particular, amenable to the cognizance of his/her state of health and personal habits, the undersigned hereby gives his/her consent to the handling of those data necessary for the conduction of the epidemiological study in question.

Date _____

Signature _____

record daily habits, domestic settings and any respiratory diseases already present in the study population or diagnosed during the course of the research.

Investigation of workers (shopkeepers)

A questionnaire (Fig. 2) was completed by the shopkeepers and managers of commercial premises situated in the center of Busalla, an area of heavy vehicular traffic.

Environmental assay

Two environmental monitoring campaigns were carried out:

March 2006

Both the indoor and outdoor concentrations of FOR and outdoor concentrations VOC were determined in the two schools, as was the concentration of VOC both inside and around the commercial premises.

October-November 2007

The concentrations of VOC were determined in the areas surrounding the Busalla school and in the external area of commercial premises in the center of Busalla.

VOC concentrations were determined by means of specific passive samplers, while FOR concentrations were measured by using radial symmetry samplers (Radiello®) able to adsorb airborne pollutants in both indoor and outdoor environments.

The devices used for VOC sampling were exposed for one week, while those used for FOR sampling were exposed for 24 hours.

On completion of sampling, the compounds adsorbed by the samplers were extracted. In the case of FOR, the samplers were desorbed by washing with a solvent,

Fig. 2. Questionnaire for shopkeepers.

Questionnaire for shopkeepers

1. SHOPKEEPER'S CODE _____

2. Sex _____

3. Place of birth _____ date of birth _____

4. Resident in _____

5. Type of commercial activity _____

6. Previous serious illnesses _____

7. Present or previous respiratory illnesses:

Illness	ascertained	on therapy
allergic rhinitis	☐	☐
respiratory allergy*	☐	☐
other allergy*	☐	☐
asthma	☐	☐
chronic bronchitis	☐	☐
pneumonia	☐	☐
irritability	☐	☐
headache	☐	☐

* specify _____

8. Do you smoke?

Cigarettes smoked per day (about) _____

9. Do you have any of the following at your shop ?

printer ☐ fax machine ☐ photocopier ☐

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and the analytes extracted were determined by means of high-pressure liquid chromatography (HPLC) using a UV detector (365 nm). For VOC, the samplers were desorbed thermally, and the compounds extracted were determined by means of gas-chromatography (GC) analysis using a flame ionization detector (FID) [15].

Statistical analysis

Statistical analysis was carried out by means of the StatView IV (Abacus Concept Inc.) program. Analysis of variance (ANOVA) was used to evaluate the significance of the differences between the mean values of the various factors, while internal comparisons were made by means of the Sheffè test.
Statistical analysis to evaluate the association between respiratory disorders and environmental pollution was carried out by means of the chi-square test and the odds ratio.

Results and discussion

In this study, we interviewed 93 children (51 male and 42 female) from the school in Busalla and 91 (43 male and 48 female) from the school in Mignanego. Table I shows the percentages of children with previous or current respiratory disorders (chronic bronchitis, allergies, pneumonia, asthma and allergic rhinitis) subdivided by geographic area.
The χ^2 test revealed correlations bordering on significance between the presence of respiratory disorders and the area analyzed (P = 0.08). It may therefore be claimed that the place of residence tends to influence the probability of developing a respiratory disorder: living in Busalla seems to increase the probability of suffering from respiratory disorders 1.91-fold (95%CI 0.92-3.99).
The questionnaire recorded the presence/absence of respiratory disorders and smoking among parents. Statistical analysis revealed a significant association between children's respiratory disorders and passive smoking among the residents of Mignanego (P = 0.05, OR = 3.01). In the same area, it emerged that children whose parents were smokers and had a history of respiratory disorders were 3.81-fold more likely to suffer from respiratory tract disorders. This confirms that the risk factor most closely associated with the development of respiratory disorders in children living in areas where air pollution is negligible is exposure to passive smoking [16-18].
The variables "parents who smoke" and "respiratory disorders among parents" did not prove to be correlated with the presence of respiratory disorders among children living in Busalla (P = 0.50; P = 0.15).
We interviewed 112 people working in 32 shops located in the center of Busalla. Possible associations between the presence of respiratory disorders and some variables regarded as "potential risk factors" (smoker, type of commercial activity and residence in the Municipality of Busalla) were evaluated. The χ^2 test did not reveal any association.
During the first monitoring campaign (March, 2006) we carried out: 20 measurements of FOR, 10 of which were taken inside the schools (5 in Busalla and 5 in Mignanego) and 10 outdoors in the vicinity of the schools (5 in Busalla and 5 in Mignanego); 10 measurements of VOC outdoors in the vicinity of the schools (5 in Busalla and 5 in Mignanego).
Twelve shops were also randomly sampled for VOC (12 VOC measurements inside and 16 VOC measurements outside the shops).
Table II shows mean concentrations ($\mu g/m^3$) of FOR measured inside and outside the two schools.
The concentrations measured inside the school buildings were clearly higher than those measured outside, thus confirming the mainly indoor origin of this substance. The principal indoor sources of formaldehyde are chipboard and plywood furnishings, formica and insulating paints.
No significant differences between the concentrations measured in the two study areas were recorded (Tab. II).
The formaldehyde concentrations measured outside the schools were comparable to the data reported in the literature on outdoor environmental monitoring [19].
Table III shows mean concentrations ($\mu g/m^3$) of VOC measured outside the two schools.
The airborne concentrations of VOC in proximity to the schools sampled did not exceed the legal limits. No significant differences between the concentrations measured outside the two schools were recorded (Tab. III).
Table IV shows the mean values of VOC concentrations measured inside and outside commercial premises.
The concentrations of VOC tot proved to be significantly higher ($P < 0.05$) inside the commercial premises than outside. This finding could be due to the presence of specific sources of VOC emissions (detergents, solvents, etc) inside the premises, which are added to those of external sources. In particular, toluene is used as a solvent for the inks used in photocopiers and cash registers. Moreover, non-negligible levels of benzene (around 3 $\mu g/m^3$) were detected both inside and outside the commercial premises; these values are probably linked to the heavy vehicular traffic in the area. On comparing the concentrations of benzene measured in the town center with those recorded in the vicinity of the school in Busalla, which is located in an area of low traffic density, a clear difference emerged. It is evident that the concentration of this pollutant is linked to the intensity of motor traffic, since it is a constituent of fuels for gasoline engines.
During the second monitoring campaign, we identified 19 points of particular environmental relevance within the Municipality of Busalla and took VOC measurements: 10 measurements in the industrial area and 10 measurements in the town center (heavy vehicular traffic).
Table V reports the mean concentrations ($\mu g/m^3$) of VOC in the two areas examined.

Tab. I. Population of the epidemiologic study subdivided by present/absence of respiratory disorders in the two areas examined.

	Busalla N. 93		Mignanego N. 91	
	N.	% (95% CI)	N°	% (95% CI)
Presence of respiratory disorders*	24	25.8 (16.9-34.7)	14	15.4 (8.1-22.9)
Absence of respiratory disorders*	69	74.2 (65.3-83.1)	77	84.6 (77.2-92.1)

* Chronic bronchitis, allergies, pneumonia, asthma and allergic rhinitis.

Tab. II. Mean concentrations (μg/m³) of FOR measured inside and outside the two schools.

	Busalla		Mignanego	
Location	Mean concentration	S.D.	Mean concentration	S.D.
Internal	20.68	9.21	19.28	2.94
External	3.26	0.52	3.25	0.24

Tab. III. Mean concentrations (μg/m³) of VOC measured outside the two schools.

	Busalla		Mignanego	
Pollutant	Mean concentration	S.D.	Mean concentration	S.D.
BZ	1.28	0.15	1.18	0.09
TO	1.99	0.32	1.73	0.32
ETBZ	0.28	0.04	0.30	0.09
mXl	0.27	0.04	0.21	0.02
pXl	0.73	0.12	0.58	0.04
oXl	0.29	0.04	0.70	0.04
VOC tot	42.52	1.99	44.19	4.79

Tab. IV. Mean concentrations (μg /m³) of VOC measured inside and outside commercial premises.

Commercial premises				
	Indoor concentration		Outdoor concentration	
Pollutant	Mean concentration	S.D.	Mean concentration	S.D.
BZ	3.21	0.72	2.85	0.70
TO	14.54	7.87	7.11	2.22
ETBZ	2.46	1.43	1.38	0.40
mXl	1.89	0.50	1.39	0.41
pXl	4.99	1.51	3.48	1.01
oXl	2.47	0.71	1.77	0.52
VOC tot	183.49	95.41	70.48	11.60

Tab. V. Mean concentrations (μg/m³) of VOC in the two areas analyzed.

Busalla				
	Industrial Area		Town Center	
Pollutant	Mean concentration	S.D.	Mean concentration	S.D.
BZ	2.14	0.81	2.46	0.83
TO	4.33	1.83	4.03	1.01
ETBZ	0.89	0.22	0.88	0.20
mXl	0.69	0.30	0.63	0.22
pXl	1.73	0.83	1.64	0.51
oXl	0.97	0.41	1.61	1.53
VOC tot	68.61	29.39	68.47	16.37

At one site in the industrial area, an anomalous TO value of 85 μg/m³ was recorded, which was probably the result of an accidental event (spillage of solvents or paints). In the analysis, this value was replaced by the mean value recorded in the area examined.

The values registered in this second monitoring campaign did not reveal any differences in contamination between the two areas under investigation. Moreover, these values were comparable to those obtained during the first monitoring campaign outside the shops situated in the town center.

In the second monitoring campaign, the concentrations of BZ were always below the benchmark value (5 μg/m³). This value refers to measurements taken over a year of sampling. Indeed, concentrations of BZ, like those of VOC in general, display wide seasonal variability, with higher values occurring in winter. This suggests that, if a summer campaign were also carried out, the mean value of BZ concentrations would be lower than the benchmark value.

Conclusions

The study did not bring to light specific health problems attributable with certainty to industrial emissions. The increased frequency of respiratory diseases reported by the inhabitants of the area can most likely be ascribed to the intensity of vehicular traffic. Although the levels of FOR and VOC measured inside the school located in Busalla and in the commercial premises in the area did not exceed the prescribed limits, they should be reduced through the implementation of a remedial protocol. This protocol should aim to reduce as far as possible the use of furnishings made of chipboard, plywood and formica and of equipment requiring solvents such as toluene. Moreover, air exchange in indoor environments should be increased through the installation of air-conditioning systems that utilize outdoor air and are equipped with filters.

This monitoring campaign confirmed the need to focus attention on the

problems of indoor contamination and traffic pollution, which proved to have a greater impact on health than that of industrial emissions. Measures must therefore be taken as soon as possible to regulate vehicular traffic in the town of Busalla in an appropriate manner, through the creation of the necessary infrastructure. More exhaustive sampling campaigns should be implemented in order to quantify the effects of specific sources of emissions and to correlate these sources with pollutants (industry, urban traffic, motorway traffic).

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■ Received on January 14, 2011. Accepted on February 16, 2011.

■ Acknowledgements. This project was financed by the Municipality of Busalla, Genoa's Local Health Authority and the Province of Genoa.

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