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PERSONAL MONITORING OF AIR POLLUTION IN THE HISTORIC CENTRE OF TURIN

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SUMMARY

This paper presents the first results of CO.S.MO (Carbon MonOxide Self Monitoring), a research program aimed at collecting data on air quality and noise levels along predetermined paths, reproducing typical walking or driving patterns in the historic centre of Turin, in order to assess the actual population's exposure to environmental pollution. Results are correlated with traffic data, meteorological conditions and urban structure.

1. INTRODUCTION

Monitoring of air quality in Italian cities is performed by the National Health Care Service (Servizio Sanitario Nazionale), through networks of fixed monitoring stations. Among the major Italian cities, Turin has one of the better developed networks, consisting of several monitoring stations, managed both by public and private institutions.

Nevertheless, experimental work conducted both in Europe and North America (1-3) has pointed out that such monitoring approach may sometimes underestimate the actual levels of exposure to environmental pollution, particularly for the population living in the historic centres, where the impact of traffic on air quality is more significant.

Concern among the City's administrators about environmental quality has risen considerably in recent years. While noticeable improvements with respect to SO_x pollution have been achieved by substituting high-sulfur fuels with low-sulfur oil and natural gas in domestic heating installations (4-5), traffic-related environmental problems have definitely become more acute.

Turin has a relatively high population (over one million inhabitants) and a relatively small historic centre, in which most of the commercial activities and services are concentrated. Furthermore, the urban layout, reproducing the orthogonal grid structure of the Roman "castrum", represents a serious constraint for any traffic management policy. In fact, plans for limiting private traffic in the city centre have been proposed and discussed as one possible solution to the problem, but limited actions have been undertaken so far. Such considerations have led the city administration to start research projects in order to gain a better understanding of urban pollution, and to promote a more effective environmental protection policy.

Aim of the CO.S.MO project (Carbon MonOxide Self Monitoring) is to assess the pollution exposure levels of people spending significant parts of their time in the city centre, through a personal monitoring campaign in which data on pollutants concentration, noise levels, traffic volume and meteorological conditions are collected using portable equipment.

A number of statistically significant paths have been identified, which reproduce typical walking or driving patterns in the city centre. Technicians carrying an instrumented backpack move along each path, while the instrumentation automatically collects and records the data. At the end of each monitoring campaign the collected data are transferred to computer memory for all subsequent elaboration.

The results of the program should provide a detailed map of the urban environmental quality, as well as inputs for identifying correlations between pollution levels and indicators such as traffic volumes, meteorological conditions, and urban structure. Furthermore, comparisons will be made between the results of personal monitoring and the data collected by the fixed monitoring stations.

2. INSTRUMENTATION

The portable instrumentation employed in the CO.S.MO project consists of the following units:

- Gas analyzer
- Air temperature sensor (Thermistor)
- Digital data logger
- Sound level analyzer/dosimeter
- Rotating vane anemometer

The main features of the instrumentation are given in Table 1.

The chemical compound that was selected as the air pollution tracer is Carbon Monoxide (CO). The choice is motivated by the fact that CO concentration is a significant indicator of traffic-related pollution, traffic being the major source of CO in urban areas.

The portable gas analyzer is an electrochemical CO detector, in which a catalytic reaction on the sensing element generates a current proportional to the gas concentration. The current is then converted to an output voltage which constitutes the input signal for a digital data logger. Air samples are collected continuously, using a built-in pump.

The data logger is a compact, microprocessor-based unit, equipped with a solid state RAM memory for data storage. Inputs may be sampled at programmable rates, ranging from twice a second to once an hour. Two analog input channels were employed, one for CO concentration, the other for air temperature. Logging features include the ability to store maximum, minimum and average values over a determined sampling interval (typically one hour), as well as statistical distributions of the results. The data logger can be interfaced with a personal computer through a standard RS-232 serial port.

In the planning phase of the research program, it was also recognized the importance of monitoring nitrous oxides (NO_x). Considering the lower reliability of portable NO_x analyzers, it was decided to utilise a different sampling technique: air is collected at the measuring locations by manually inflating tedlar bags of five liter capacity; the bags content is then analyzed in the laboratory.

Noise pollution is monitored using a solid state Sound Level Dosimeter/Analyzer. Construction, dimensions and programming capabilities of this instrument are fully equivalent to those of the data logger. The noise indicators that were recorded are the Equivalent Sound Pressure Level L_{eq} -- i.e., the energy-averaged sound level over the sampling period -- the minimum and maximum levels over the sampling period, and the statistical levels L_{10} and L_{90}. All levels are measured in dB(A). The instrument's specifications comply with ANSI S1.4-1983, ANSI S1.25-1978 and IEC 651 standards.

Calibration of each instrument was checked before the beginning of the monitoring campaign against laboratory-grade instrumentation.

TABLE 1
Specifications of the instrumentation

CO analyzer	
Full Scale Ranges	0-50 / 0-100 (ppm)
Accuracy	± 2.0% of full scale
Repeatability	± 0.5% of full scale
Minimum Detectability	1.0% of full scale
Linearity	± 1.0% of full scale
Zero Drift (24 hours)	± 1.0% of full scale
Span Drift (24 hours)	< ± 2.0% of full scale
Lag time	less than 1 second
Sound level analyzer	
Operating Range	45-140 (dBA)
Amplitude Linearity	± 0.5 dB at 1kHz
Amplitude resolution	0.1 dB
Sampling Rate (Fast)	32 samples/second
Sampling Rate (Slow)	8 samples/second
Frequency Response	A and C weighting
Detector	True RMS

3. SAMPLING METHODOLOGY

The area under investigation was subdivided into two zones, as indicated in Figure 1: the inner zone is the area in which private traffic limitations have been envisaged by the city administration; the outer zone represents the semi-central perimetral belt that would be mostly affected by traffic limitation measures concerning the inner zone.

The first two sampling campaigns were conducted in the months of December 1988 and February 1989 within the inner zone only. The same five sampling paths were examined in each campaign. Sampling time for each path amounts to twelve continuous hours, between 8.00 A.M. and 8.00 P.M.; weekdays only were considered.

Each path is a closed loop consisting of six adjacent streets or squares. For each street or square a monitoring time of one hour is allocated. The sampling procedure includes three ten minutes stops at selected locations, one corresponding to a high intensity traffic site (crossroads, traffic lights, bus stops, etc.), the other two to average traffic conditions; the balance time (thirty minutes) is needed to reach the various sampling positions, check the instrumentation, etc. While CO concentration, air temperature and noise level are automatically recorded, wind speed, air relative humidity and traffic volumes are measured manually.

Completion of one sampling path therefore requires six hours. Each path is monitored twice daily, the first time during the "morning" (08.00 to 14.00 hours) and the second time during the "afternoon" (14.00 to 20.00 hours). Each campaign, consisting of five paths, takes up one working week.

At the end of each day, the sampled data are transferred to computer memory and the instrumentation is checked. The data transfer and checking procedure requires approximately one hour.

Selection of the sampling paths was based on a preliminary analysis of the urban structure, taking into account both the potential for airborne pollutants dispersion ("canyon type" streets, traffic intensity, critical intersections, etc.) and the sensitivity to environmental pollution linked to the destination of the area (schools, hospitals, shopping districts, etc.). Some of the sampling locations correspond to critical situations such as shopping along a street, regulating traffic at a major inter section, standing at a bus stop or at a taxi deposit, etc.

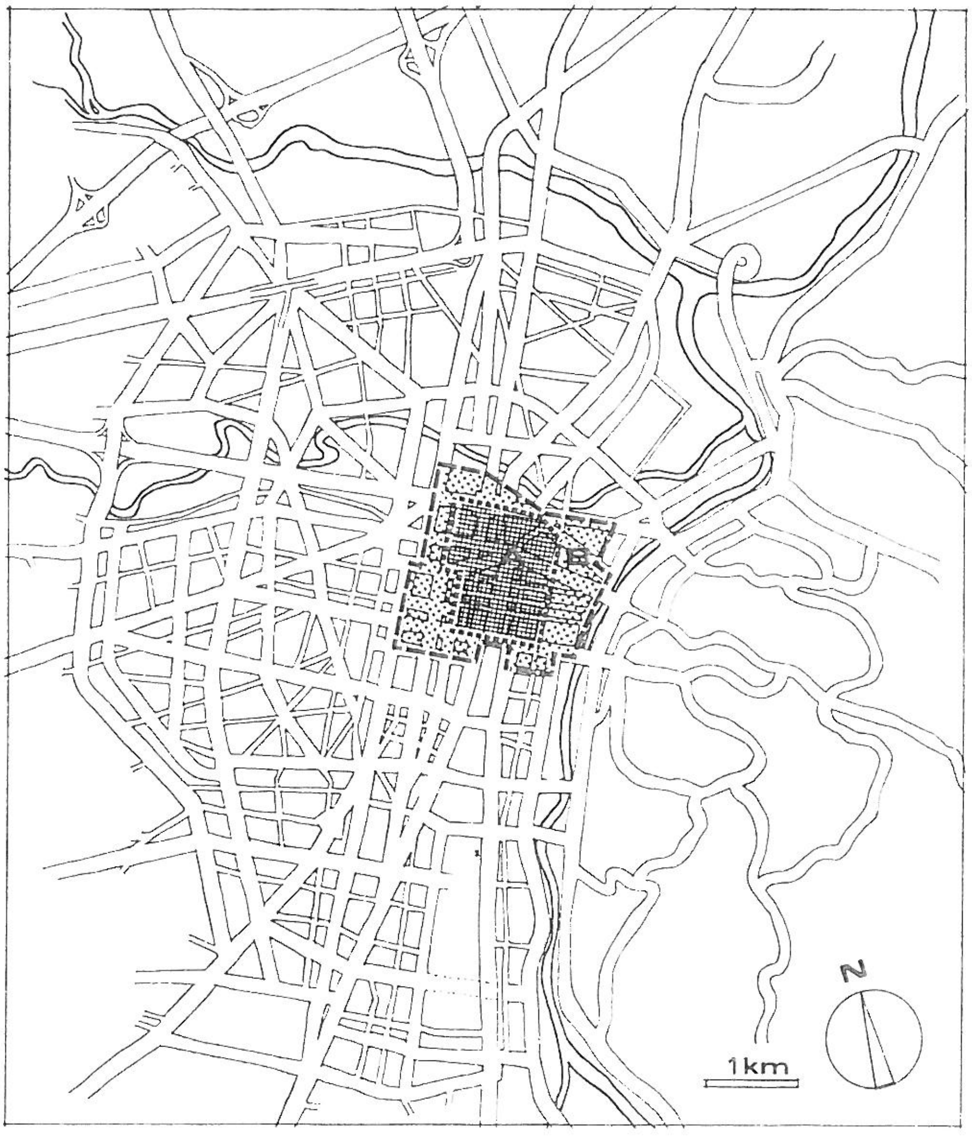

Fig. 1. Plan of the center of Turin:
a - inner zone b - perimeter zone

4. RESULTS AND CONCLUSIONS

The results presented in this paper refer to the first two sampling campaigns, in which the same five paths were examined twice, respectively during the months of December 1988 and January 1989. A summary of the main results is given in Table 2: each line of the table refers to one path (i.e., to one sampling day, in which each path is examined once in the morning and one in the afternoon). The meaning of the data is given at the bottom of the table. Notice that eight-hour average CO concentrations are considered, since a legal limit for such value is specified by the Italian legislation. No reference is made in this paper to NO_x, because data processing is still under way.

TABLE 2
Summary of the first two sampling campaigns (Dec.88 and Jan.89).

Path	CO_{8h} (ppm)	CO_{mx} (ppm)	CO_{pk} (ppm)	L_{eq} (dBA)	L_{90} (dBA)	L_{10} (dBA)	T_{ave} (°C)	W_m (m/s)	TT (#/h)
1	6.2	18.4	54.2	72.3	66.1	74.8	11.2	2.5	1024
1	10.3	22.3	53.3	72.3	65.1	74.7	9.8	0.7	1055
2	10.7	22.3	51.3	70.8	62.0	72.7	8.3	1.0	727
2	8.7	19.8	38.3	71.8	62.7	74.1	10.4	0.3	721
3	8.4	15.1	32.5	71.0	63.3	73.4	4.1	0.8	1145
3	5.8	13.4	31.1	71.5	63.0	73.8	8.9	0.9	1363
4	12.9	19.7	40.5	71.5	64.4	73.9	7.7	1.5	955
4	6.5	9.8	20.2	72.3	64.1	74.7	7.5	2.2	1008
5	3.3	7.2	31.5	70.0	60.8	72.6	3.3	1.5	475
5	4.5	7.9	22.8	69.7	61.1	72.5	2.4	1.3	390

CO_{8h} = CO concentration (eight-hour average)
CO_{mx} = CO concentration (maximum of hourly averages)
CO_{pk} = CO concentration (instantaneous peak value)
L_{eq} = A-weighted equivalent sound pressure level (daily average)
L_{90} = Sound level exceeded 90% of the time (daily average)
L_{10} = Sound level exceeded 10% of the time (daily average)
T_{ave} = Ambient temperature (daily average)
Wm = Wind speed (instantaneous daily maximum)
TT = Total (light + heavy) hourly traffic (daily average)

Although the number of experimental data available so far is limited, some preliminary comments can be made from their analysis:

1 The 1988-89 winter season has been exceptionally dry and mild, compared to average. The frequent occurrence of temperature inversion conditions, coupled to the absence of rain over twelve consecutive weeks, caused much concern among the public authority in Turin and other Northern Italian cities. However, in our surveys the hourly CO concentration never exceeded the legal limit of 34.9 ppm (the maximum hourly average value was in fact 22.3 ppm, with an instantaneous peak concentration of 54.2 ppm); on the contrary, the eight-hour average CO legal limit (8.7 ppm) was exceeded for three out of ten paths.

2 Daily trends of meteorological and traffic conditions indicate that early morning (08 ÷ 11) and late afternoon (18 ÷ 20) hours, when high traffic levels and atmospheric inversion are most likely to coincide, are the most critical periods in terms of air pollution, as pointed out by the following analysis of data averaged

over three-hours:

Period	[CO] (ppm)	Temp.(°C)	Hourly traffic
08 ÷ 11	10.4 ±5.3	4.8 ±2.5	952 ±726
12 ÷ 14	4.9 ±2.3	8.0 ±3.7	729 ±519
15 ÷ 17	6.5 ±3.8	9.1 ±3.6	976 ±702
18 ÷ 20	7.5 ±4.4	7.5 ±3.3	886 ±611

Based on the above results, it can be argued that a significant correlation exists between CO concentration and ambient temperature, since higher CO values always occur at lower ambient temperatures. Wind speeds were usually quite low during the surveys (never exceeding 2.5 m/s) and do not seem to have a big influence on the results. Furthermore, no clear correlation appears between CO and traffic, partly because the statistical significance of three-hour average traffic data is low (standard deviation is in fact of the same order of the average value); however, it must be specified that no better correlations were found using hourly average data (not given in the paper).

3 For each street or square, noise levels show a very limited variation between samplings: this fact indicates that a "noise pollution label" can be actually attributed to individual streets or squares. This is due to the following factors: both the noise emission level, which depends mostly on the presence of heavy traffic (buses, trolleys and waste collection trucks), and the sound field characteristics are "street-dependent". In general, hourly L_{eq} values ranged between 68 and 77 dB(A), with an average of about 72 dB(A).

The first results of the CO.S.MO project confirm the usefulness of the personal monitoring approach. The experimental data are consistent with those provided by fixed monitoring stations, and confirm the correlation between air pollution and atmospheric stability; no clear direct correlation was on the contrary identified between air pollution and traffic levels. Noise pollution is site-dependent, clearly a function of traffic type and street morphology. The undergoing developments of the project address the issues of NO_x pollution and the comparison with the data provided by the fixed monitoring stations.

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