Modelling, Measurement and Control C
Vol. 79, No. 3, September, 2018, pp. 133-139
Journal homepage: http://iieta.org/Journals/MMC/MMC_C

Experimental study of air pollution in the urban centre of the city of Messina

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https://doi.org/10.18280/mmc_c.790311

Received: 1 May 2018
Accepted: 3 June 2018

Keywords:
air pollution, measurement instruments, mobile data-logger

ABSTRACT

In this paper is described an experimental study about air pollution in the urban centre of the city of Messina. This survey was carried out with the analysis of the data collected during an indoor/outdoor monitoring campaign that were four kinds of particulate: 0.3 μ, 0.5 μ, 1 μ e 5 μ, carbon dioxide, light and heavy vehicular traffic data, and the following thermic and hygrometric parameters: air temperature, relative humidity, atmospheric pressure, wind direction and speed. All data surveys were accomplished in seventeen designed fixed positions situated in the center of the city, close to high capacity urban roads and to rail and nautical intersections. Only carbon dioxide was measured in eight fixed positions situated in the center of the city. Beside of the 17 fixed monitoring stations were also measured indoor values of particulate ad air temperature. Measurement instruments used were Abacus 301 for particulate, a thermo-hygrometer, a thermo-anemometer, a data logger Babuc ABC for measuring carbon dioxide. Vehicular traffic surveys were monitored in the 17 stations every hour. A linear regression analysis of the data highlighted that the air of the expressways of the urban centre of Messina is richer in contaminants than other parts of the city. In this paper is also reported an advanced method for air pollutants monitoring based upon a data-loggers mounted on the transports of the communal transportation society of Messina. Furthermore are explained the experimental measurement instrument used for monitoring data and the system of acquisition, recording and transmission data in real time. Acquired data, localized with GPS, may be useful for constructing or updating pollution maps in real time in the main roads of the city.

1. INTRODUCTION

The situation of environmental quality of urban areas nowadays represents a worldwide problem worsening increasingly. The continuous and growing requests for new technology and comfort, by today's society, involves the use of processes that require more energy in both the industrial and civil sectors. This increase in energy demand, if no sustainable energy is used, contributes significantly to the increase in levels of environmental pollution. Pollutant emissions are mainly made up of combustion products that are developed in the energy production, air-conditioning of the environment and handling in the transport sector. In particular, the air pollution of anthropogenic origin is emitted mainly from large fixed sources (industries, plants for the production of electricity and incinerators); from small fixed sources (domestic heating systems) and from mobile sources (vehicle traffic).

Many of these sources are closely linked to the production and consumption of energy, particularly fossil fuels. The use of fossil fuels for domestic heating, in particular heavy fuel oil, biomass and coal are a significant source of environmental pollution of particulates and sulfur dioxide, especially in temperate regions (especially in China and Europe of East).

Even car traffic contributes largely to the emissions of these pollutants in cities characterized by a large vehicular congestion, and this because of the presence of a huge series of motor vehicles fueled by traditional fuels (petrol and diesel fuel especially in Asia).

In cities where gasoline and diesel are still used, vehicle traffic can contribute 70-80% to the increase in concentrations of these polluting gases in the atmosphere.

As for the other main pollutants, it should be noted that in the emission of ozone and volatile organic compounds, anthropogenic sources play a fundamental role as much as natural ones; combustion generally represents the main cause of nitrogen oxide emissions; the engines of the means of transport are typically the main cause of carbon monoxide emissions.

These pollutants in addition to compromising the area, next to the emission sources, are transported over long distances, react chemically with the substances present in the atmosphere, giving rise to the formation of secondary pollutants, such as acid rain and ozone production.

In the most industrialized countries atmospheric pollution in the last century has reached threshold values worrying for the health of the inhabitants.

One of the main sources of urban pollution is the high number of cars and other vehicles circulating on the roads that causing essential changes in atmospheric air concentration, saturating air with contaminant particles and gases. Exhaust emissions from these vehicles produce the main greenhouse gases that are carbon dioxide, nitrogen oxides and particulate emissions [1-5].

This problem has become particularly prominent considering its dependence on meteorological parameters.

2. DESCRIPTION OF ANALYZED SITE

This study reports the results of an experimental study about air pollution in the urban centre of the city of Messina.

This city represents an important point of passage for light and heavy motor vehicles, from Sicily to the rest of Italy and in the opposite direction.

Because the main roads are expanded along a south-north direction the city is interested by a high traffic pollution.

The data collected during this survey consisted of concentrations of four types of particulate, carbon dioxide concentrations, light and heavy vehicular traffic data, air temperature, relative humidity, atmospheric pressure, wind direction and speed; all this parameter was measured during an indoor-outdoor monitoring campaign [6-8].

Monitored data was collected in seventeen designed fixed stations situated in central areas of the city, characterized by high levels of vehicular congestion especially in rush hours.

The monitoring stations were equipped with Abacus 301 for analyzing particulate, a thermo-hygrometer, a thermo-anemometer for measuring climatic parameters and a data logger model Babuc ABC for measuring carbon dioxide. Carbon dioxide concentrations were collected only in eight stations; all the data were monitored every hour.

In this paper is also reported the correlations of pollutants concentration with thermo-hygrometric parameters and with vehicular traffic and was effectuated a linear regression analysis.

This analysis revealed that the air of the expressways of the urban centre of Messina is richer in contaminants than other parts of the city.

In this research was also experimented an innovative method for thermo-hygrometric parameters monitoring based upon a data-loggers mounted on the transports of the communal transportation society of Messina.

In the future this method will be applied for measuring pollutants concentrations.

This system of acquisition was useful for recording and transmission data in real time.

Acquired data, localized with GPS, may be useful for constructing or updating pollution maps in real time in the main roads of the city.

3. MEASURING EQUIPMENT AND EXPERIMENTAL METHOD

Measurement instruments used during the monitoring period of this survey were Abacus 301 for measuring particulate, a thermo-hygrometer, a thermo-anemometer, for measuring climatic parameters and a data logger model Babuc ABC for measuring carbon dioxide.

Carbon dioxide concentrations were collected only in eight stations; all the data were monitored every hour.

Particles counter Abacus 301 (Fig.1), by *A.&L. CO. Industries*, is simple to use and maintain, it is equipped with internal batteries and interfaces with external PC.

Figure 1. Counter particles abacus 301

It is furnished with four fixed sizing channels at 0.3, 0.5, 1.0, and 5.0 microns.

Data automatically are stored in a 500 sample memory that can be downloaded to a portable printer or personal computer through a built-in RS232 communications interface.

It is designed for micro contamination assessment in clean rooms and other environmentally-controlled areas.

For measuring relative humidity and wind speed has been used the thermo-hygrometer hot-wire anemometer (Fig, 2), that measures temperature and air humidity, and the wind speed.

This instrument uses a very fine wire, on the order of several micrometers, electrically heated to some temperature above the ambient temperature.

Figure 2. Thermo-hygrometer and thermo-anemometer

This instrument uses a very fine wire, on the order of several micrometers, electrically heated to some temperature above the ambient temperature.

Air flowing past the wire cools the wire; as the electrical resistance of most metals is dependent upon the temperature of the metal a relationship between the resistance of the wire and the flow speed permits to measure wind speed.

For measuring CO_2 was used the Babuc ABC data logger. It is a measuring equipment constituted by a set of instruments useful for recording meteorological, climatologically and environmental data (Fig. 3).

It is formed by a spectrophotometer, a direction and wind speed sensor, a thermo-hygrometer, a barometer and a central unit that records, analyzes and transmits environmental data (Fig. 4).

Figure 3. Babuc ABC data logger: central unit and probes

Figure 4. Component of data logger

The experimental method carried in this work was based on three main work stages:

(1) stations selection;

(2) particles and CO_2 monitoring;

(3) vehicular traffic (light and heavy vehicles) monitoring.

Data surveys were accomplished in seventeen station that delineate a central area of the city of Messina, through a reticular map; pollutants monitored were particulate in all seventeen stations and CO_2, only in eight stations. Four dimensions of particles were detected: 0,3 μ, 0,5μ, 1μ and 5μ, which represented a significant risk to human health [9-20].

The measurements have been effectuated indoor and outdoor.

The surveys were monitored every hour from 7:00 a.m. to 7:00 p.m. for the outdoor measurements and from 7:15 a.m. to 7:15 p.m. for indoor measurements.

Were also measured air temperature, wind speed and relative humidity, for indoor measurements, and wind speed and relative humidity for outdoor measurements

Carbon dioxide was monitored only outdoor from 7:00 a.m. to 7:00 p.m. Vehicular traffic has been analyzed every hour 7:00 a.m. to 6:00 p.m.

4. ANALYSIS OF CARBON DIOXIDE CONCENTRATIONS

Carbon dioxide is a greenhouse gas, it absorbs and emits infrared radiation causing carbon dioxide the warming of the surface and lower atmosphere and, at the same time the cooling of the upper atmosphere.

The growth in atmosphere of CO_2 concentrations and other long-lived greenhouse gases such as methane, nitrous oxide and ozone have strengthened their absorption and emission of infrared radiation, causing the rise in average temperature of the Earth since the middle of 20th century. A very high percentage of carbon dioxide into the atmosphere is a result of the use of fossil fuels.

Carbon dioxide data were collected in eight monitoring stations named: “Landing stage-Caronte”, “Viale Boccetta Basso (Villa Mazzini)”, “Viale Boccetta Alto (Archimede High-School)”, “University Square”, “Square XX Settembre”, “Aironi Square ”, “Viale Italia”, “Viale Garibaldi (Vittorio Emanuele Theater)”.

The trend of carbon dioxide means values during the day of measuring in the “Dock stage Caronte” monitoring station is reported (Fig. 5).

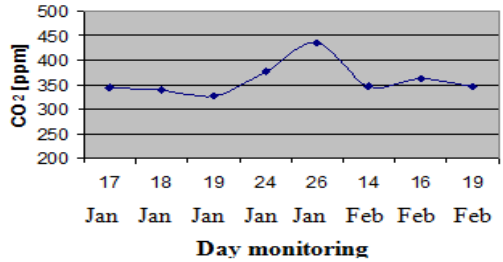

Figure 5. Trend of carbon dioxide mean values

High values of carbon dioxide concentrations were measured in the three sites of “Imbarcadero Caronte”, “Viale Boccetta Basso (Villa Mazzini)” and “Viale Boccetta Alto (Archimede High school)

The station “Landing stage-Caronte” is situated near the dock of the Society “Caronte” for sailing light and heavy vehicles from the continent to Sicily and in the opposite direction, the two stations named “Viale Boccetta Basso (Villa Mazzini)” and “Viale Boccetta Alto (Archimede High school)” are situated near the highways from Messina to the other cities of Sicily.

As these stations are interested by an enormous commuter traffic the relations of carbon dioxide with traffic were studied. In the stations at the same time in which was executed the monitoring of carbon dioxide were collected the numbers of heavy and light vehicles and motorcycles passing through.
The number of equivalent vehicles was after calculated, using the formula

$$V_E = M_L + 2\,M_P + 0.5\,M$$

with:

M_L = number of light vehicles;
M_P = number of heavy vehicles;
M = number of motorcycles.

The analysis of correlation between CO_2 and V_E shows a positive coefficient value of 0.532 and, of consequence, a dependence relation between carbon dioxide and vehicular traffic.

Table 1 shows the values of CO_2, air temperature, relative humidity and air atmospheric pressure, wind speed and direction and traffic flows, measured during the monitoring period at the “Caronte Landing stage” station.

Table 2 shows the values of the traffic flows, and the corresponding values of the equivalent noise level $L_{eq(A)}$, measured during the monitoring period at the Dock stage Caronte station.

Table 1. Values parameter detected in the "Caronte" station

STATION "IMBARCADERO CARONTE"						
DATE	CO_2 [ppm]	Air Temp. [C°]	Air Humidity [%]	Air-Pressure [hPa]	Wind [m/s]	Wind Direction
17 Jan	343	11,3	56,8	1025,3	1,1	SW
18 Jan	340	11,2	54,2	1020,1	1	SW
19 Jan	328	13,5	72,9	1014	1,4	WSW
24 Jan	376	13,3	34,9	1016,4	0,73	WSW
26 Jan	436	9,1	47,9	1018,9	8,82	SSW
14 Feb	347	10,1	39,6	1009,5	0,98	NE
16 Feb	363	11,5	57,0	1015,7	0,72	ESE
19 Feb	346	19,7	50,6	1008,1	0,64	Calm

Table 2. Values of the traffic parameter and noise level $L_{eq}(A)$ monitoring in the "Dock stage Caronte" station

STATION "IMBARCADERO CARONTE" TRAFFIC FLOW					
DATA	Number Light Vehicles	Number Heavy Vehicles	Number Motorcycles	Equivalent Vehicles	Leq dB(A)
14 Feb	592	38	52	694	73,5
16 Feb	680	40	99	809,5	73,9
19 Feb	538	4	42	567	72,2

5. ANALYSIS OF PARTICULATE CONCENTRATIONS

Particulates anthropogenic represents the most dangerous air pollutant, it may be carcinogenic because it is able to penetrate deep into the lungs and blood streams unfiltered; it may cause also permanent DNA mutations. Human activities such as the burning of fossil fuels in vehicles, power plants and various industrial processes produces significant amounts of particulates.

In this study the analysis of the dependence between particulate and vehicular traffic produced very significant results. Were measured four types of particles: 0,3µ, 0,5µ, 1.0µ e 5.0µ.

The chart in Fig.6 reports the trend of vehicular flows versus particles 0,3µ sized during the observation time, measured in a day of the monitoring, every hour from 6:00 a.m. to 6:00 p.m.

From this chart it is possible to notice how high values of particles were collected during rush hour, from 12:00 a.m. to 3:00 p.m.

High values of particulate were measured in the "Viale Boccetta Alto (Archimede School)" station.

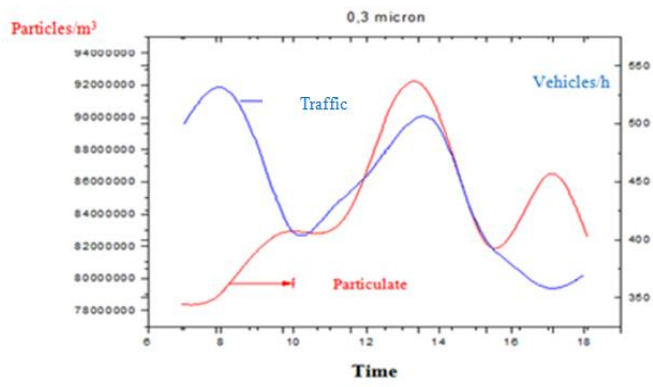

Figure 6. Trend of particles sized 0, 3 versus vehicular traffic

From the point of view of the correlations between the trend of particulate concentrations and the vehicular traffic very significant was revealed the "Viale Europa- Ghibellina street" station.

It is noticed that particles sized 0.3, 0.5 and 1.0 are linearly correlated with the trend of vehicular traffic.

This isn't true for particles 5 sized, its weight influences suspension time causing the longest permanence in air of little particles.

6. ANALYSIS OF INDOOR AIR QUALITY

For verifying that urban outdoor air pollution can be an important contributor to the indoor air quality, was effectuated an analysis of indoor air in some houses near the outdoor measurement stations.

This study was executed in indoor spaces situated in buildings near the seventeen monitoring outdoor stations.

The pollutant investigated was the particulate of four types 0.3, 0.5, 1.0 and 5. The analysis revealed high values of particulate indoor in correspondence of the outdoor stations that revealed high values of particulate concentrations.

7. MEASUREMENTS WITH MOBILE SYSTEMS

The analysis performed by the authors in this paper resulted in agree with a study effectuated with the data of air pollution monitored by the Metropolitan City of Messina [6-8, 21].

The City of Messina attended on the monitoring of urban pollution in four fixed stations situated in central areas of the city.

After a long period of inactivity, the air quality detection network owned by the Metropolitan City of Messina was reactivated with effect from 1 May 2015.

For technical/economic reasons it was possible to restart only a part of the analyzers installed in the various stations.

Following an agreement protocol with ARPA Sicilia, the instrumental equipment in some stations has been integrated with equipment owned by ARPA.

The following Table 3 shows the monitored parameters and the recorded exceedances.

Table 3. Annual report on air quality, VI Env. Direction Messina

	Pollutants											
Station	PM_{10}		NO_2		SO_2			CO	C_6H_6	O_3		
and period	Annual Average g/m^3	Number of exceed. g/m^3	Annual Average g/m^3	Number of exceed. g/m^3	125	Number of exceed. g/m^3	Number exceed of g/m^3	Number of exceed 10 g/m^3	Annual Average g/m^3	Number of exceed of mg/m^3	Number exceed of 180 g/m^3	240
Year 2015 1 May - 31 Dec												
Boccetta	160		390					0	0.8		00	
Caronte	2113								1.05		75	
Villa Dante								0	0.8			
Year 2016 1 Jan -31 Dec												
Boccetta	235		392					0	0.5		00	
Caronte									1.39		00	
Villa Dante	191							0	0.96			
Year 2016 1 Jan -31 Dec												
Boccetta	225		312					0	0.85			
Caronte								0	1.49		074	
Villa Dante	196							0	0.91		097	
Tremestieri			230					0				

The diversities of the urban fabric, greatly influence the spread of pollutants, this effect makes insignificant the measurements from fixed stations, which are generally installed in open places.

To get a more detailed view of the situation, it is necessary to install a large number of stations throughout the city, but this is not feasible for obvious following reasons: costs related at the control systems management and maintenance.

A possible solution to the problem, is to integrate the fixed monitoring network, with mobile stations, simple and inexpensive, mounted on public transport in urban and/or suburban transport.

The means of public transport, in constant movement on the main roads, represent a virtual network, consisting of a large number of measuring stations.

For the purpose of obtaining more accurate measuring of air quality parameters, in the city of Messina since 2004, for monitoring air pollutants a new methodology have been applied.

This method is based upon an experimental measurement instrument for monitoring data and upon at system of acquisition, recording and transmission data in real time.

The measurements instruments consisted of data-loggers mounted on the transports of the communal transportation society of Messina.

Acquired data by this system, localized with GPS, may be useful for constructing or updating pollution maps in real time in the main roads of the city.

Different from use of fixed stations, with the collaboration of the Agency of Urban Transport of Messina (A.T.M.), first two trams have been used to acquire the data in movement.

It allows to get, in real time, covering in full the urban heart of the city.

Implementing a database is useful for analyzing the quality of the air through the use of models of "atmospheric diffusion" that is maps of iso-concentrations of primary and secondary pollutants, favoring besides the studies about the environmental degrade related to the historical-artistic-architectural patrimony of the city with a sort of "map of degrade".

It is possible to trace maps of climatic parameters, the coefficient of diffusions, the profiles of winds and the thermal gradients that permits to take place that particular phenomenon named "urban heat island" [5], Fig.7.

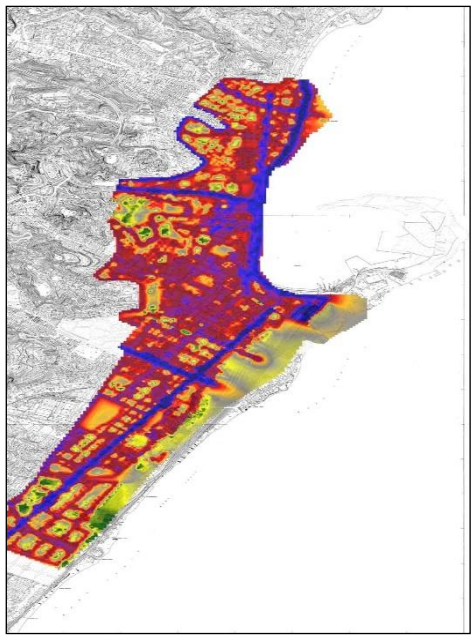

Figure 7. Sketch of the urban heat island in in the Messina city

The parameters collected by the use of such acquisition system are relative of many physical-technical aspects: the environmental aspect, with the characterization of the main pollutants, acoustic aspect, by the characterization of main

sources of noise and their levels of acceptability, the thermo-hygrometric aspect, by the study of the variations of relative humidity and temperature, the visual aspect, by the study of reduction of natural illumination caused by smog.

In Fig. 8 are highlighted in green, the mobile detection stations, during which the medium in motion during the experimental campaign, has acquired and transmitted in real time the data to the central management unit.

The Authors executed numerous tests for implementing the acquisition data system and the transmission data system.
In this way they succeed to improve the measurement strategy.

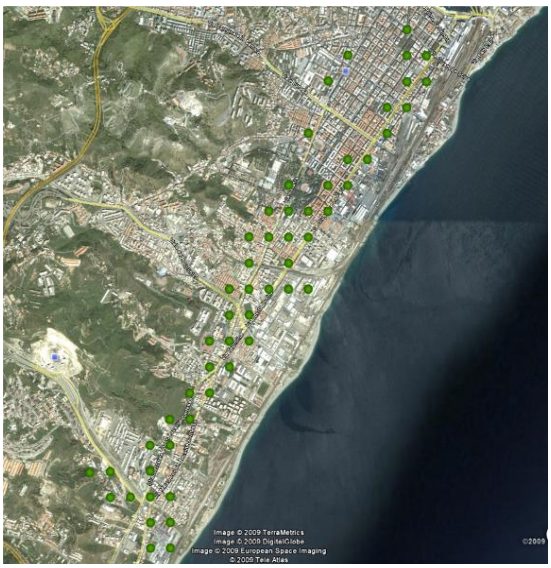

Figure 8. Data tracking stations from moving vehicles

They obtained the implementation of a "time and distance" measurement strategy in which the data were acquired, only if the vehicle has covered an assigned distance, from a measure point to another or only if a fixed time gap was elapsed between a measure and the next one.

This measurement strategy allows to avoid the storing of too many data in a same measure point, e.g. at bus stops, and it allows to spacing out the data when the vehicle is moving at different speeds.

8. DATA ANALYSIS AND CONCLUSIONS

A study about the situation of environmental quality of the urban centre of the city of Messina has been reported in this paper.

Particularly, by a monitoring survey in the center of the city, the Authors analyzed the concentrations of particulate with diameter less than 0.3, 0.5, 1.0, and 5.0 microns and carbon dioxide.

All the measuring sites were situated close to high capacity urban roads and to rail and nautical intersections because the purpose of this analysis has to study the correlations between the concentrations of carbon dioxide and particulate and vehicular traffic.

Carbon dioxide data were collected in eight monitoring stations named: "Dock stage Caronte", "Viale Boccetta Basso (Villa Mazzini)", "Viale Boccetta Alto (Liceo Archimede)", "University Square", "Piazza XX Settembre", "Cairoli Square ", "Viale Italia", "Viale Garibaldi (Vittorio Emanuele Theater)".

The analysis of carbon dioxide concentrations revealed that high values of carbon dioxide concentrations were measured in three sites respectively situated near the dock of the Society "Caronte" for sea transport of light and heavy vehicles from Italy to Sicily and in the opposite direction, and near the highways connecting Messina with the rest of Sicily, daily interested by enormous vehicular flows.

These stations are daily interested by an enormous commuter traffic so in the stations at the same time in which was executed the monitoring of carbon dioxide were collected the numbers of heavy and light vehicles and motorcycles passing through.

Using a formula reported in literature has been calculated the number of equivalent vehicles V_E daily passing through these stations and was effectuated a correlation analysis.

This analysis showed a positive coefficient value and a dependence relation between carbon dioxide and vehicular traffic.

High values of particulate concentrations were measured in the site "Viale Boccetta Alto (Liceo Archimede)" station, near the highways where there were elevated vehicular traffic.

Moreover high values of particles were collected during rush hour, from 12:00 a.m. to 3:00 p.m.

Particularly the Authors noticed that lightest particles are linearly correlated with the trend of vehicular traffic, and they had a longer permanence time in air in respect of heavy particles.

Simultaneously with the outdoor measurements were effectuated an indoor measurements campaign of particulate in some buildings near the seventeen monitoring outdoor stations.

High values of particulate indoor were detected in correspondence of the outdoor stations that revealed high values of particulate concentrations demonstrating that urban outdoor air pollution can be an important contributor to the indoor air quality.

For the purpose of obtaining a more realistic situation of air pollution in the city of Messina, an innovative method for air pollutants monitoring was set up since 2004.

The Authors occupied of the implementation of a prototype of a standalone unit for the acquisition and transmission of geo-referenced environmental parameters. It was a data-logger mounted on the trams and buses of the communal transportation society of Messina.

The collected data were Temperature, Relative Humidity, Carbon Monoxide, Ozone, and six kinds of Particulate $PM_{0,3}$, $PM_{0,5}$, PM_1, PM_2, PM_5, PM_{10}.

The executive phases of the data acquisition standards unit were acquiring physical quantities, recording position data, downloading the data in real time and storing all data.

Acquired data, localized with GPS, may be useful for constructing or updating pollution maps in real time in the main roads of the city.

The advantages of a virtual monitoring network composed by moving means of transportation, may be useful for universities and research centers, a wide and exhaustive knowledge of urban microclimatic and pollution conditions appears extremely interesting for the improvement in urban heat island investigations.

Also for the Public Transportation Companies, availability in real time of geo-referenced data is absolutely necessary for fleet control, for information at users about wait times at the stops or about service breaks, for telecontrol of vehicles and

mechanical working, and for the actions of measures precautionary, for the staff abuses or vandalism gestures.

The study of concentrations of CO and Particulate effectuated with mobile equipment could be particularly interesting and useful, particularly for the governs for stating regulation policies on traffic composition, or on aging and maintenance of the cars.

Future researches of the Authors, based on this innovative method will be also oriented toward the study of bioclimatic indexes for the determination of the environmental risk, using the parameters measured by moving sensor together with other parameters such as direct and diffuse solar irradiation, wind speed and direction from fixed stations.

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