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Assessment of the impact of the vehicular traffic on BTEX concentration in ring roads in urban areas of Bari (Italy)

Maurizio Caselli [a], Gianluigi de Gennaro [a,b,*], Annalisa Marzocca [b], Livia Trizio [a,b], Maria Tutino [a]

[a] Dipartimento di Chimica, Università degli Studi di Bari, via Orabona, 4, 70126 Bari, Italy
[b] LEnviroS s.r.l., spin off dell'Università degli Studi di Bari, via Orabona, 4, 70126 Bari, Italy

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ABSTRACT

A BTEX monitoring campaign, consisting of two weekly periods, was carried out in Bari, south-eastern Italy, in order to evaluate the impact of the vehicular traffic on the air quality at the main access roads of the city. Twenty-one sampling sites were selected: the pollution produced by the traffic in the vicinity of all exits from the ring road and some access roads to the city, those with higher traffic density, were monitored. Contemporarily the main meteorological parameters (ambient temperature, wind, atmospheric pressure and natural radioactivity) were investigated. It was found that in the same traffic conditions, barriers, buildings and local meteorological conditions can have important effects on the atmospheric dispersion of pollutants. This situation is more critical in downtown where narrow roads and high buildings avoid an efficient dispersion producing higher levels of BTEX. High spatial resolution monitoring allowed both detecting the most critical areas of the city with high precision and obtaining information on the mean level of pollution, meaning air quality standard of the city. The same concentration pattern and the correlation among BTEX levels in all sites confirmed the presence of a single source, the vehicular traffic, having a strong impact on air quality.

1. Introduction

Gaseous air pollutants are recognized to cause health effects, essentially in individuals with pre-existing disease. In particular, highly reactive volatile organic compounds (VOC) which are reported to be toxic and also may participate in numerous reactions in the atmosphere to form secondary air pollutants including ground level ozone and secondary organic fine particles (Griffin et al., 1997; Rappengluck et al., 1998). VOC sources are both anthropogenic and natural ones; the most important sources of VOCs in Europe are (ESIG, 1997, European Solvents Industry Group, Brussels, Fernandez-Villarrenaga et al., 2004): transportation (35%), solvents use (24%), vegetation (22%), production processes (7%) and combustion power (6%). Benzene, ethylbenzene, toluene, and xylenes, known collectively as BTEX, represent a significant fraction of the volatile organic compounds emitted in urban atmospheres (Singh et al., 1992; Bailey and Eggleston, 1993; Zielinska et al., 1996). Major sources of BTEX include vehicle exhaust, automobile service stations and industrial emissions. The vehicular emissions come from different contributions: exhaust emissions (cold and hot), evaporative emissions, and emissions from brake and tyre wear. Transport-related emissions are important factors in determining air quality in many urban regions, depending on the altitude and thus the dispersion pattern of emissions. In most urban areas, air pollution is now badly affecting the quality of life and the improvement of air quality has become a priority for most cities in developed countries. For this reason BTEX are constantly monitored in many Italian cities from Environmental Protection Agencies (EPA) by using the air quality monitoring networks. The benzene limit value for the protection of human health fixed for 2008 by the European Directive 2000/69/CE is 5 $\mu g\ m^{-3}$ with a margin of tolerance of 2 $\mu g\ m^{-3}$. Several studies showed that benzene exposure has serious health effects as it is a geotaxis carcinogen (Snyder and Kalf, 1994; Zhang et al., 1996; Lovern et al., 1997; Wiwanitkik, 2008; Pilidis et al., 2009).

Benzene is a Group I (known human carcinogen) under the IARC (International Agency for Research on Cancer) classification system (IARC, 1999). A large number of studies provided a strong association between occupational exposure to benzene by inhalation and an increased incidence of certain types of leukaemia. The World Health Organization (WHO) considered that an exhibition continued to benzene of 1.7 $\mu g\ m^{-3}$ might cause 10 cases of leukaemia per 10 000 inhabitants and seeing later the results of the above mentioned concentration in some point and especially in the second campaign what supposes a risk in the health of his inhabitants (WHO, 2000). To limit health risks, the European Directive 2000/

* Corresponding author at: Dipartimento di Chimica, Università degli Studi di Bari, via Orabona, 4, 70126 Bari, Italy. Tel./fax: +39 0805442023.
E-mail address: giangi@chimica.uniba.it (G. de Gennaro).

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69/EC required that the yearly mean concentration of benzene in atmosphere must be less than 5 μg m^{-3} within the year 2010 (European Union Parliament and Council, 2000). Other alkylbenzenes cannot be classified as carcinogenic compounds, since there are inadequate evidences for human carcinogenicity. Many studies showed the several effects linked to the exposure to these pollutants (Cragg et al., 1989; Low et al., 1989; IARC, 1999; Saillenfait et al., 2003). The environmental aspects of transport sustainability are concerned with local atmospheric pollution. In fact in developed and industrialized countries, traffic is the most important source of high pollution levels in towns and thereby also high exposure of the population in the ambient environment (Liu et al., 2000; Hertel et al., 2001; Fernandez-Villarrenaga et al., 2004; Zhao et al., 2004; Khoder, 2007). Vardoulakis et al. confirmed that the road traffic in Paris can be considered as the main source of these pollutants in the ambient air (Vardoulakis et al., 2002). Fernandez-Villarrenaga et al. carried out measurements in Coruna, a medium sized town in Spain, and they showed that traffic emissions were the main source of BTEX in the studied area.

Bruno et al. studied toluene to benzene ratios in other southern Italian cities, Canosa di Puglia and Taranto, confirming that the vehicular traffic was the main source of VOC in the urban area (Bruno et al., 2006; Bruno et al., 2008). The hardships associated with urban mobility, air pollution and noise are a cause for concern. However, even though most towns and cities have serious traffic problems, the number of vehicles and the urban traffic continue to grow, thereby contributing to the deterioration of the life quality and health of the inhabitants. Urban sustainable mobility is a strategic objective for all cities. In order to obtain this aim it is necessary to find solutions that reconcile the quality of mobility with air quality; then to meet the needs of society and its citizens. The aim of this work was to investigate the impact of the road network on the urban air pollution levels and to demonstrate as the results obtained can be useful for the planning of the Mobility Urban Plan. Therefore a monitoring campaign of benzene, toluene, ethyl benzene and xylenes (BTEX) air concentrations were performed in Bari, a city in southern Italy. In particular the pollution levels produced by road traffic in the vicinity of all exits from the ring road and some access roads to the city, those with higher traffic density, were assessed. The monitoring campaigns were carried out with diffusive samplers, that offer numerous advantages as regards to traditional methods, such as simplicity and rapidity of analysis, low cost and weight (van Aalst et al., 1998 and Wright et al., 1998). They are constituted by inactive materials and many of their components (the adsorbing cartridge, the cylindrical diffusive body, and the supporting plate) can be reused. Moreover, they do not need a power supply, in field calibrations and maintenance. The possibility of contemporaneously using a large number of samplers for many days and in different climatic conditions allowed a high resolution monitoring, useful to have both detailed information on the critical states of the air quality and a screening vision.

2. Materials and methods

2.1. Sampling sites

A monitoring campaign, consisting of two periods, was carried out in 2008 in Bari. Bari is located in south-eastern Italy on the Adriatic coast, in the Region of Puglia of which it is the regional capital. The city counts around 400 000 inhabitants and has a surface of 116.2 km^2. Thanks to its favourable geographic position, Bari is a developed centre of commerce, agricultural products, and fishing. The industrial area has progressively moved outside the town, and is today lodged among the towns of the province. An important ring road runs around the city and connects the north to the south of Bari Municipality for a total length of 27 km and a traffic flow of about 80 000 vehicles day^{-1}. Two monitoring periods ranged from 21 to 28 April 2008 (first period) and from 30 September to 7 October 2008 (second period) were performed in order to investigate two different seasonal conditions. Twenty-one sampling sites were selected at the main arteries of the city (Fig. 1): the BTEX levels produced by road traffic in the vicinity of all exits from the ring road and some access roads to the city, those with higher traffic density, were monitored. Most sampling sites were located along roads having about the same width (two lanes) except for the site 5 that was on a road with four lanes and the sites 18–20 that were located along narrow roads of the urban area and characterized by high buildings. The site 21 was placed close to the port area. Monitoring was planned taking into account the guidelines of the "Guidance Report on Preliminary Assessment under EC Air Quality Directives" which describes the principles (distance from the road, representativeness of the site, etc.) to carry out a preliminary evaluation of spatial distribution of volatile pollutants (van Aalst et al., 1998). Moreover the traffic density and the architecture of the city were considered for the selection and location of the sites in order to obtain data as representative as possible of the mean concentration levels of pollutants for each area.

2.2. Sampling method

BTEX were sampled with Radiello® diffusive samplers (Fondazione Salvatore Maugeri, Padova, Italy) suitable for thermal desorption. The sampling system is made up of a cylindrical adsorbing cartridge housed coaxially inside a cylindrical diffusive body of polycarbonate and microporous polyethylene. The cartridges are composed by a cylindrical stainless steel net (100 mesh) with the external diameter of 4.8 mm, containing 350 mg of 35–50 mesh of Carbograph 4. Before the sampling, the cartridges were conditioned and analysed to verify the blank levels (Bruno et al., 2005). Each sampler was exposed for a week and after sampling it was sealed in a sealed glass tube and brought to the laboratory for the analysis. Contemporarily the main meteorological parameters (ambient temperature, wind speed and direction, atmospheric pressure and natural radioactivity) were monitored. Municipality of Bari is supplied of an efficient air quality automatic monitoring network composed of five stations located in the urban area. Each monitoring station is equipped with a BTEX analyser and meteorological sensors, therefore the data collected in these stations were considered in this study. Planetary boundary layer (PBL) mixing monitoring (FAI Instruments, Fonte Nuova, Italy), located in the urban area of Bari near the University, was used for radon measurement. Reliability of BTEX radial diffusive sampler for thermal desorption during field measurements were assessed in our previous work (Bruno et al., 2005). In particular repeatability of the Radiello® sampler, the influence of sampling time under field conditions (1-d exposure, 3-d exposure, and 7-d exposure), and the inter-comparison with automatic instruments were studied. It was found that the mean%RSD for 7-d exposure was lower than 12% and independent of the sampling time. These results showed that radial passive samplers for TD are sufficiently reliable for BTEX monitoring in atmosphere.

2.3. Analytical method

The analyses were carried out by using a thermal desorber (Markes International Ltd, Unity™) equipped with an autosampler (Markes mod. ULTRA™ TD) provided with 100 positions and coupled with a gas chromatograph (Agilent GC-6890 PLUS) and a mass selective detector (Agilent MS-5973N). The thermal desorber provides a two-stage mechanism: in the former the analytes are des-