MAPPING AIR POLLUTION IN URBAN TIRANA AREA USING GIS

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ABSTRACT

The recent development of spatial data infrastructure in the frame of geographic information systems (GISs) has created the new era of different applications in the field of environment. The scope and the scale of urban areas problems make the GIS a powerful tool for management of spatial and temporal data, complex analyses and visualization. The ability to manage a number of spatial and temporal data formats, data structures created in the frame of the GISs open the ways to building air quality information systems that synthesize geospatial and temporal air quality data to support spatial-temporal analysis and dynamic modeling. Mapping of air pollution within a GIS environment for 6 selected points at the urban area of Tirana during 2009 was developed. Surveys for air pollutants as NOx, NO_2, O_3 and SO_2 were conducted using passive sampler Analyst based on European Directive (EC Directive 96/62 EC ed EC Directive 99/30) that indicates the passive sampling as an indicative method for preliminary evaluation of air quality. Two-one month periods over winter and summer period are chosen to expose the passive samplers. The pollutant concentrations for each period are visualized in the planar view of the Tirana urban area. GIS was used to compare the two planar views representing the periods of passive sampling in order to investigate the influence of meteorological conditions. The visualized result has the potential to provide valuable information for pollution impact analysis, by including also the dimension of the influenced area and population. The spatial assessment of air pollution within Tirana urban area can be exploited by environmental and medical authorities in order to plan their future strategies.

Key word: Air pollution, GIS, passive sampling, Tirana

1. INTRODUCTION

Usually, air pollution monitoring in urban environments is performed by operating a certain number of monitoring stations located in several sites which are representative of the general exposure to pollution by population (Allegrini I., et al, 2002).. In such situations, pollutant concentrations are measured by means of proper analyzers. Such a

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conventional approach, although found satisfactory in many instances, has a number of definite limitations: standard monitoring stations require high investment costs, extensive maintenance and training and highly specialized personnel, data gathered by automatic analyzers are not suitable for a rapid interpretation and, unless used to compare the values with pre-defined limits or air quality standards, they are not always useful. Another method to assess pollutant concentration is based on the use of diffusive devices which is an ideal tool to determine the pollutant distribution over a large area and to assess integrated concentration levels, over long period of time. The different techniques are used in the monitoring process in order to determine the individual factors of pollution and stress of the urban environment, to estimate short term and long term changes and to develop models that can simulate a real environmental situation to aid the decision making process. Considering the nature of collected measurements, the research requires a spatio-temporal data management. The increase in computing power and graphics is facilitating the advance of geographic information systems-GIS, which can effectively satisfy these tasks. Capabilities of the GIS include mainly management of spatial data in the form of map layers, which can visualize real objects by vector and raster data formats together with graphs and multimedia presentations. Data analysis in the frame of the GIS represents one of the next steps. A number of definitions describe capabilities of the GIS to solve a wide range of environmental problems, which are related to urban areas. Burrough (1998) defines the GIS as a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes. The GIS contains a huge range of spatial analyses and temporal comparisons, which allow carrying out and display of output data in the GIS's layers. Air pollution maps are potentially powerful tools particularly for urban areas for use in epidemiological studies. They can help to identify the "hot-spots" in need of special investigation or monitoring. In Tirana urban area according to 2007 traffic data, average traffic counts have increased 13.1% over the previous year and have been climbing at about that same rate for the past 7 years. The combined increase in road traffic and lack of significant improvement in road infrastructure has caused chronic congestion on all principle roads and dangerously high levels of pollution. Vehicle emissions are responsible for the majority of CO, hydrocarbons, NOx, SO_2 and inhaled particulate matter present in the atmosphere of the city (Kim J.J., et al, 2001). Due to increasing attention devoted to the direct health risks associated with air pollution from local traffic sources, two-one month passive monitoring field campaign were conducted during year 2009. Mapping of air pollutants as NOx, O_3 and SO_2 is visualized in the planar view of Tirana urban area using GIS. The planar visualization is displayed to improve its interpretability and to point the hot spots where the highest pollution occurs which can be easily detected by representing pollution level using an appropriate color ramp. The spatial and temporal of air pollution in Tirana urban area is investigated based on ambient air quality levels in summer and winter. At the same time the influence of meteorological conditions is analyzed.

1. METHODOLOGY

The assessment of atmospheric pollution in urban area is a very important step for the definition of locations where to deploy the monitoring stations. Such locations are selected according to several information, which include: type and intensity of emitting sources; distribution of polluting sources in the urban area; expected maximum

concentration points in relationship to the presence of human targets (population exposition); prevailing meteorological conditions; model applications; geographical context; other proper studies (Allegrini I, et al, 2002).. The monitoring sites have to be representative of a sufficiently large area in the vicinity, so that the sampling station can be considered representative of a larger area or representative of sites characterized by similar environmental conditions. The methodology of this study is based on grid selection which is used to identify the measuring points (figure 1) and a number of 6 points is defined. Every point is chosen to represent as well as possible the air pollutants emission sources of the entire grid to which it belongs. It takes also accounts of traffic flow and the number of the inhabitants per grid. An area of influence for each sample was defined considering a circle of 200 m of radius. This choice is partially arbitrary but it was a result of the attempt to locate the passive samplers on a grid. A receptor grid is elaborated with a distance between points of 200 m. The data was structured and stored in the temporal database while Tirana's digital map at scale 1: 20000 was being uploaded and topologically structured using ArcView and ArcInfo GIS software. The location of stations in the maps was determined. Attribute data were assigned to spatial objects and the system become ready for spatio-temporal analysis and management. After the experimental campaigns, the results of this technique are complemented by proper studies, which take into account for the location of emitting sources, the distribution of exposed population and the prevailing meteorological conditions.

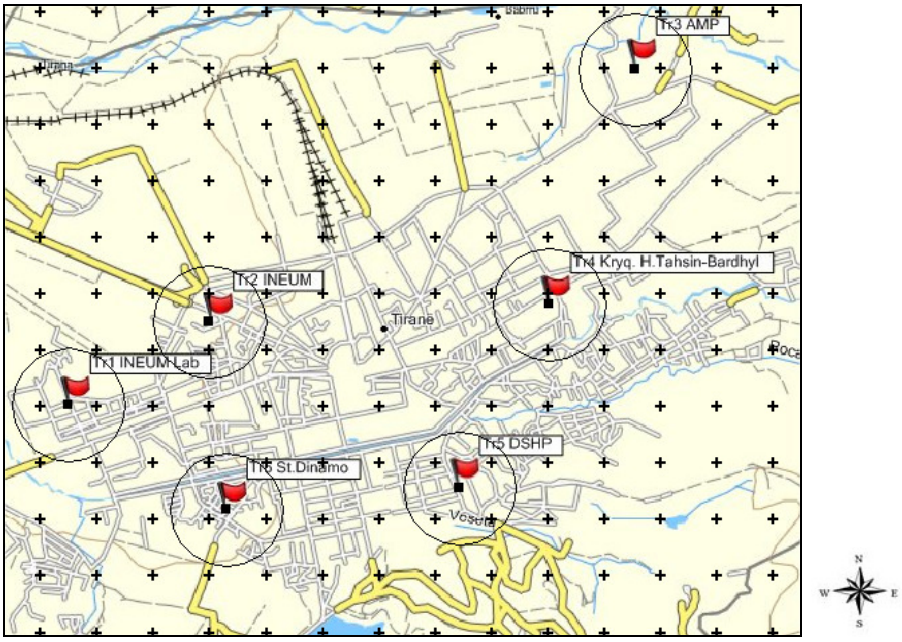

Figure 1. Tirana urban area and the passive monitoring points

2.1 Site description

Tirana city is located at the central part of Albania and is the capital of the country. The greater urban area occupies ~31 km^2 and extends approximately 25 km far away from Adriatic Sea. At a distance of approximately 7 km of the eastern part are the foothills of Dajti Mountain, (1612 m maximum height). The western part is surrounded by small hills, whose height is ~400 m. Topography, is not intense to the northwestern part of the city, so air from the sea could reach the urban area via this physical channel, when sea breeze circulation is developed. In the urban area of Tirana live ~700,000 inhabitants (INSTAT, 2005), but most likely the population is increase thenceforth. The area is dominated by a Mediterranean climate with dry and hot summer. The main wind direction during summer is NW and during winter is SE. The wind velocity is lower during almost all year (figure 2).

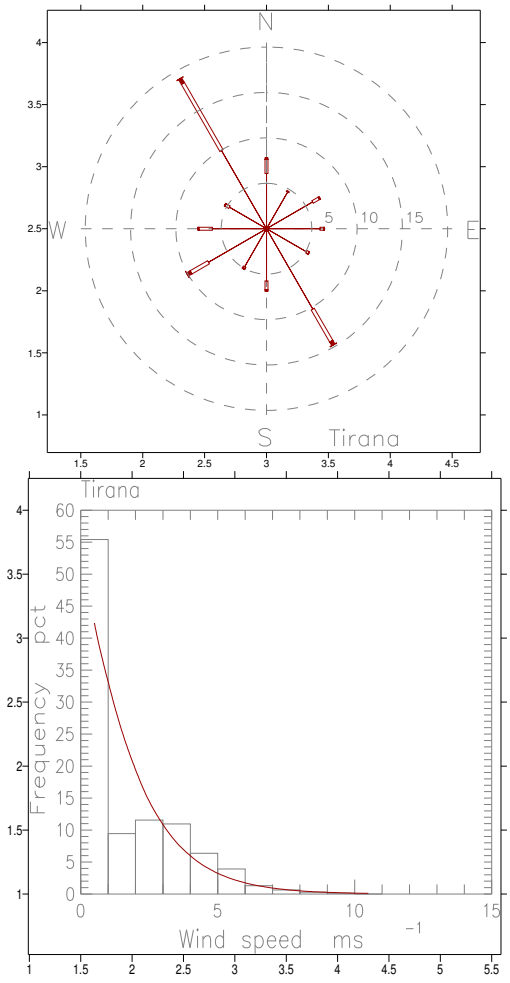

Figure 2. Wind direction and wind velocity in Tirana area

2.2 Passive sampling

Measurements with passive samplers turned out to be an appropriate method when one wants to get a spatial distribution of air pollution (Brown R. H., 1993).. With passive samplers, it is possible to measure NO_2, NOx, SO_2, O_3 and some other pollutants as well. The key principle for passive samplers is the Fick's diffusion law and the transport of pollutant molecule from entrance of the sampler to its end, where membrane with absorbent is located. Among several kinds of passive samplers that have been developed, Analyst® samplers are chosen for this purpose. The Analyst®, was developed, patented and certified by CNR (Rome, Italy), by the Institute for Atmospheric Pollution (Primary Reference Laboratory for Atmospheric Pollution), as equivalent method for the determination of the concentration in ambient air of sulphur dioxide, nitrogen oxides, and benzene in accordance with Italian legislation. The Analyst® (Manes F. et al, 2003) has been tested over a relatively long periods of time and their performances are documented in a large number of scientific publications. Since the technique is very inexpensive, a large number of passive samplers may be deployed in the urban environment (Seinfeld J.H., et al, 2006) in order to gain detailed information about spatial distribution of pollution and about the occurrence of sites where the exposition of population is at high levels. The ambient concentration of NO_2, NOx, and SO_2 is known to follow a seasonal cycle (Lin Y.T.,et al,2001) with peak values in winter and lower concentrations during summer period while O_3 seasonal cycle present higher values during summer period and lower values during winter. For this reason the first one-month sampling campaign was conducted during 13 March – 16 April 2009 when elevated values of NO_2, NOx and SO_2 are expected and the second sampling campaign was conducted during period 03 July – 04 August 2009 when elevated values of O_3 are expected. During our campaigns, samplers were exposed together with shelters. We fixed shelters with samplers on different objects. We chose mainly traffic lights, street lights, trees or something similar. Samplers were set 2,5-3,5 m above the ground and depending by the site type 0,5-300 m away from road-side. Samplers exposed for one-month, after installation were collected in the same order they were deployed. The Analyst® samplers were sent to the Italian institute in order to be analyzed using the Ion-Chromatography method. The monitoring sites code, the description of measuring points, their typology and the time of passive sampling exposure are presented in table 1. It can be seen that we have chosen two traffic sites, two urban sites, one suburban site and one background site.

Table 1. Monitoring sites, typology and time of exposure

Site code	Description	Typology	Pollutants	Exposure time (min)	
				Exped.1	Exped.2
TR 1	IEWE Lab	suburban	O_3,NOx,NO_2	47545	43266
TR 2	IEWE	traffic	O_3,NOx,SO_2	47465	43194
TR 3	AEF	background	O_3,NOx,NO_2	47500	43218
TR 4	Ring road-H.Tahsin cross	traffic	NO_2,NOx,SO_2	47487	44765
TR 5	Directory of Public Health	urban	O_3,NO_2,SO_2	47415	43224
TR 6	Dinamo Stadium	urban	NOx,NO_2,SO_2	47406	43350

3. RESULTS AND DISCUSSIONS

The analysis reveals that Tirana urban area is characterized by more than one hot-spot related to pollutants as nitrogen oxides and ozone. For this reason the analysis is focused on these pollutants and a comparison between two expeditions is conducted in order to investigate the influence of meteorological conditions. The figures 3 & 4 present the comparison between two passive sampling periods for the nitrogen dioxide. It can be seen that site Tr2 presents levels of nitrogen oxides during both expeditions approximately 3 times higher than the annual limit value equals to 40 $\mu g/m^3$ of the National Standard of Air Quality (NSAQ). This site situated at the eastern part of the city center and directly at the cross-road with elevated traffic is capable to represent the peak values of nitrogen oxides and sulphur dioxide concentrations. Due to the fact that the content of the sulphur in fuels is low the sulphur concentration doesn't overcome the limit value of the NSAQ. It can be seen that the nitrogen dioxide concentrations are more elevated during the cold period which is related to the influence of the meteorological conditions that tends to trap the pollutants at the layers near the surface. During summer period, due to the mixing of the atmosphere layers related to the elevated temperature and high solar radiation, the nitrogen oxides and sulphur dioxide concentrations are lower.

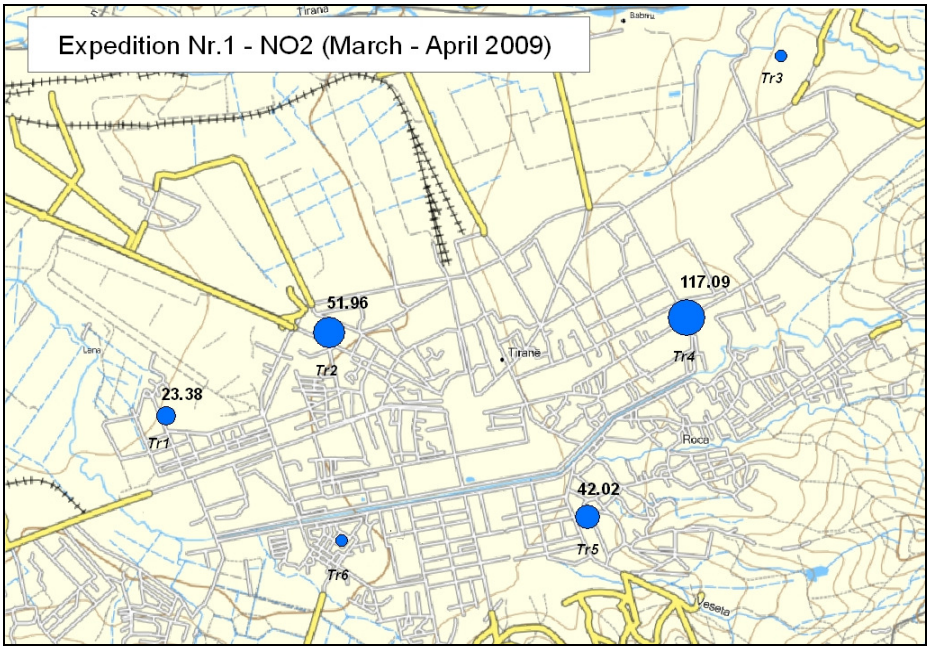

Figure 3. NO_2 concentration in Tirana urban area, expedition I

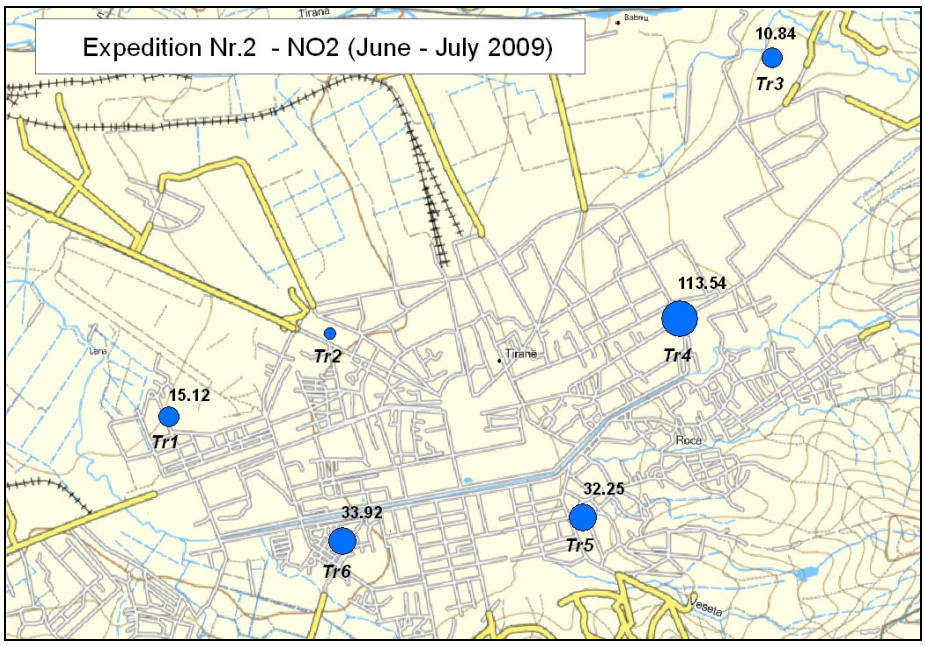

Figure 4. NO_2 concentration in Tirana urban area, expedition II

In figures 5 & 6 is presented the comparison between two passive sampling periods for ozone. It can be seen that the ozone concentrations at sites Tr1, Tr3 and Tr5 are higher than at the other sites. Site Tr1 present levels of ozone which are higher than the limit value of 65 μg/m^3 of the NSAQ. This site is situated to the western part of the city center and the main source of pollution is the construction activity. Since the site is situated at the city suburbs it is capable to represent adequately the peak values of ozone concentration. The ozone concentrations measured are more elevated during summer period when the photochemical reactions are present due to the effect of high solar radiation and air temperatures.

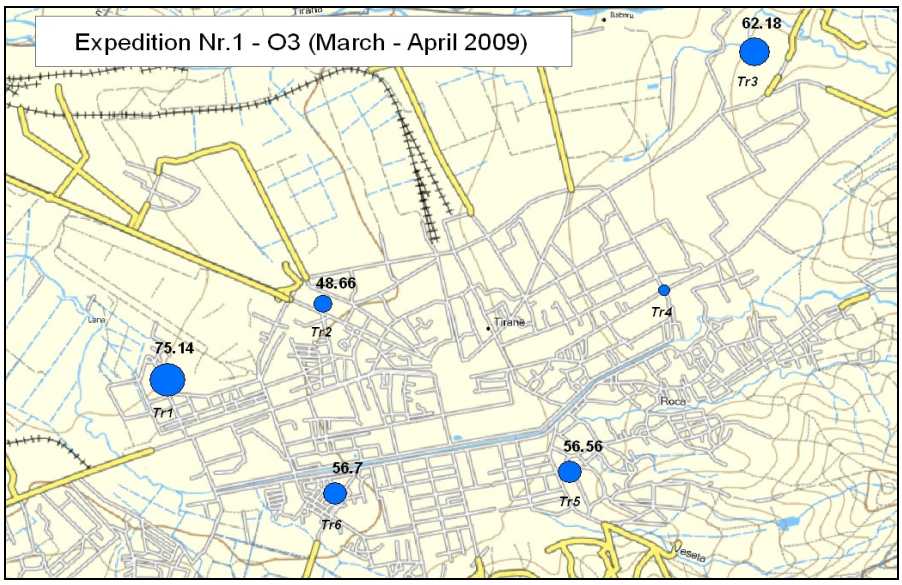

Figure 5. O_3 concentration in Tirana urban area, expedition I

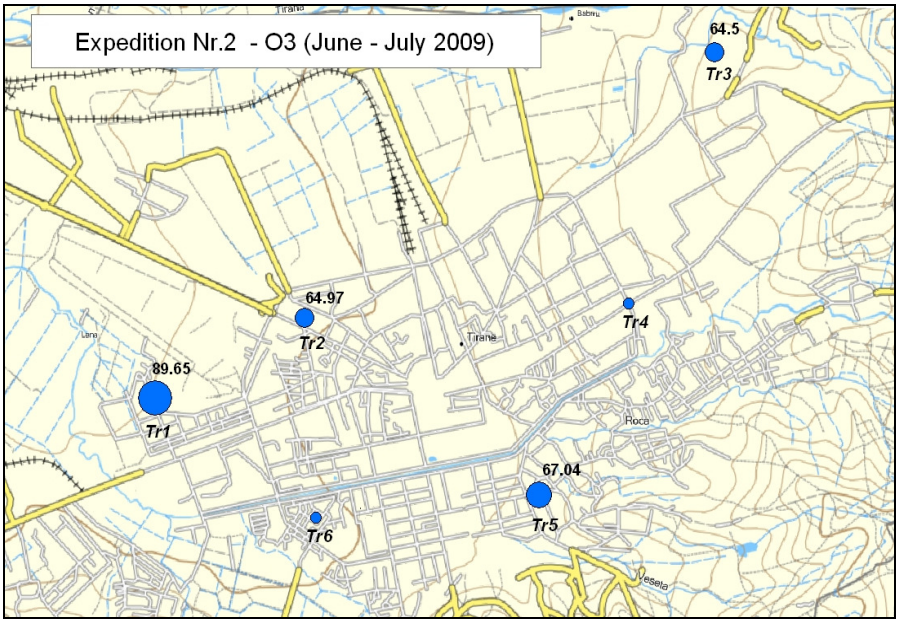

Figure 6. O_3 concetration in Tirana urban area, expedition II

4. CONCLUSIONS

GIS is one of the important technologies which help us to monitor, analyze and decide on the air pollution quality in the urban area. The Tirana urban area is characterized by more than one hot-spot site mainly influenced by the road emissions. The highest nitrogen oxides values were found near streets with high traffic volume. The ambient air quality situation for ozone is strongly influenced by the meteorological conditions. Obtained data from passive monitoring process show that the pollution levels in Tirana urban area are going higher. This problem leads us through creating a statistically valid surface which subsequently is used in GIS for optimum decision making based on the air quality factors which can be collected as maps and ground stations data. Geostatistical methods are urgently needed for the amount of pollution in everywhere. The spatial assessment of air pollution within Tirana urban area can be exploited by environmental and medical authorities in order to plan their future strategies.

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M.Sc. Albana ZOTAJ is a GIS and remote sensing specialist. She has worked as a researcher at the Geographic Center of the Academy of Sciences till 2008. For the last 4 years she has held the position of Head of GIS & Remote Sensing Department at the Geographic Center. Her main responsibilities were to find foreign and domestic partners through different kinds of projects and the management of them. During her career she has participated in a number of projects as consultant. Through these activities, she gained extensive knowledge and experience in the fields of GIS and mapping and she is well acquainted with the availability and quality of the existing map material in Albania as well as the existing GIS environment