

The Athens International Airport and air quality

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Abstract

The Athens International Airport "Eleftherios Venizelos" began operation in March 2001. The Airport Company's Environmental Department, which has been certified according to ISO 14001, ensures compliance with environmental regulations and seeks to continuously improve the airport's environmental performance. The objective of this paper is to illustrate in detail the airport's comprehensive approach to air quality management. Exposure of the surrounding population is monitored with a multi-station Air Quality Monitoring Network (AQMN). Concentrations of ozone, particulate matter, oxides of nitrogen, carbon monoxide, sulphur dioxide and hydrocarbons are monitored along with basic meteorological parameters. A structured database was created for the AQMN, including the necessary programming to automate the quality control of the raw data based on scientific criteria and processing in accordance with accepted guidelines. Furthermore, the Airport Company is in the process of installing additional monitoring equipment, including a sound radar (wind profiler) and a Differential Optical Absorption Spectroscopy (DOAS) system. Finally, various company-wide measures are taken to reduce pollutant emissions as well as energy consumption.

Keywords: Athens International Airport, Air Quality Monitoring Network, high quality dataset, SODAR, DOAS, GreenLight.



1 Introduction

A project development history of more than 20 years preceded the official commencement of the construction works for the new Athens International Airport. The Athens International Airport (AIA) is considered a pioneer international Public-Private Partnership of its type in the world, being the first major Greenfield airport constructed with the participation of the private sector. The Greek State holds 55% of AIA's shares, while the private sector partner comprises private shareholders who collectively hold 45% of the Airport Company's shares. AIA is managed and operated as a private sector company. The airport has two runways and in its current capacity can accommodate 16 million passengers a year and 600 aircraft movements per day.

The Environmental Department of AIA was established from the first day of the company's operation in 1996. AIA is the first Greek airport with an Environmental Department certified according to EN ISO 14001 (December 2000). Based on the principles of sustainable development and continuous improvement and within the framework of the Environmental Management System (EMS), AIA focuses on the areas of aircraft noise, air quality and meteorology, resources monitoring, water management, waste management, natural environment, cultural heritage and community projects.

The assessment of the atmospheric environment in the vicinity of the airport is one of AIA's priorities. Air quality is monitored by an extensive network, installed and operated in the neighbouring area of Messogaia. In addition, new monitoring systems are in the process of being installed and several measures are taken to improve air quality.

2 Air Quality Monitoring Network (AQMN)

2.1 History

In 1998, AIA installed an Air Quality Monitoring Network in the Messogaia area, in the Municipalities where the installation of air quality monitoring stations was foreseen by the Airport's Ratifying Law (Law 2338/95). The technical requirements of the AQMN were developed in cooperation with the Technical University of Athens and the Aristotle University of Thessaloniki.

2.2 Description

The AQMN consists of six stations: five stationary (Spatha, Pallini, Markopoulo, Koropi and Glyka Nera) and one mobile. The station locations were chosen in such a way as to cover the regions neighbouring the airport, along the prevailing wind directions (see Figure 1) as defined in the Airport's Ratifying Law: north of the airport (Pallini), northwest (Glyka Nera), southwest (Koropi), south (Markopoulo) and the region closest to the airport (Spatha). During the construction phase, the Mobile station was originally placed within the airport premises. It was later relocated to the Municipality of Artemis northeast of the



airport. There it remained from July 2000 to May 2003. In July 2003 it was relocated to an area within the airport to provide benchmark data for the DOAS system the airport intends to install and operate in 2004. Table 1 summarises the station characteristics (location, coordinates and height above mean sea level) of all stations of the AQMN. The station classification is based on the EC Directive 97/101.

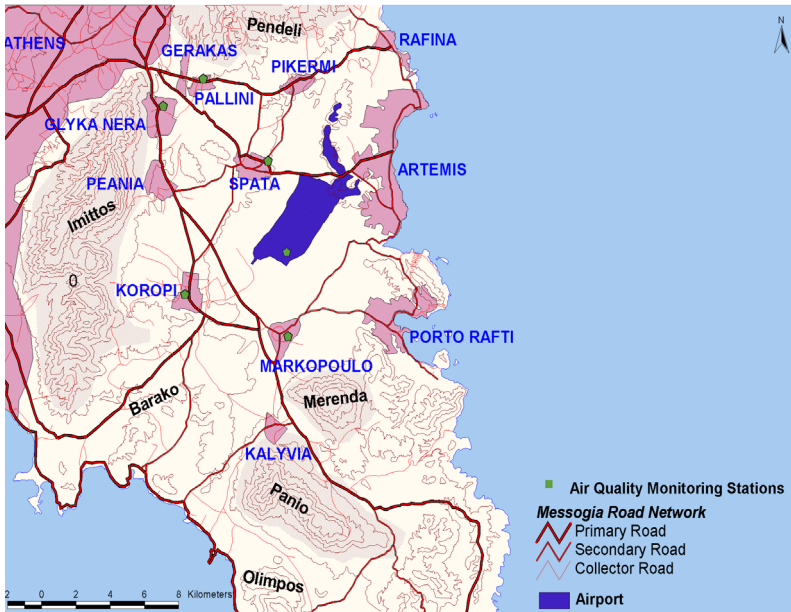


Figure 1: Map of Eastern Attica showing the location of the Airport and the AQMN stations.

Table 1: Characteristics of AQMN stations.

Station	Location	Latitude Longitude	Height above mean sea level (m)	Classification
Spata	Health Center	37° 57' 58'' 23° 55' 23''	155	Background Urban
Pallini	High School	38° 00' 18'' 23° 53' 17''	180	Background Suburban
Glyka Nera	Fouresi hill	38° 00' 11'' 23° 50' 56''	250	Background Urban
Koropi	Health Center	37° 54' 58'' 23° 52' 34''	110	Traffic Urban
Markopoulo	High school	37° 53' 10'' 23° 56' 05''	100	Background Suburban





Figure 2: Photograph of the Spata station.

The stations are installed at the ground level (Spata, Glyka Nera, Koropi,) or at the building roof at a height of 10 m above the ground (Markopoulo, Pallini), consistent with the directives of the European Environmental Agency [1, 2]. The stations are equipped with analysers measuring the near ground concentrations of the air pollutants: NO_x , O_3 , PM_{10} , CO , SO_2 , hydrocarbons (HC) and BTX (benzene, toluene, xylene) according to the standard methods of the European Union. The sampling tube for all air pollutants is installed at a height of 4 m above the ground; except for the PM_{10} tube that is installed at a height of 6 m. Table 2 presents the analysers that are available in every station. Moreover, all stations are equipped with meteorological sensors, measuring air temperature, relative humidity, wind speed and direction. The measurements for all parameters are continuous with an integration time of half an hour.

As far as data quality is concerned, it should be mentioned that the above network is regularly serviced and calibrated by experienced technicians.

Table 2: Air pollutants measured at the AQMN stations.

Station	NO_x	O_3	PM_{10}	CO	SO_2	HC	BTX
Spata	√	√	√	√	√	√	√
Pallini	√	√	√	√	√		
Glyka Nera	√	√	√	√	√		
Koropi	√	√	√				
Markopoulo	√	√	√				
Mobile	√	√	√	√	√	√	√

To determine the levels of heavy metals and PAHs, external scientific bodies perform analyses periodically and the relevant reports are delivered to AIA.

2.3 Data collection and processing

The equipment installed in both the measuring stations and AIA's offices is used for data collection, transfer, control, storage, processing and presentation including controls for correct operation of the measuring equipment.

For data collection, an appropriate data acquisition system is installed in each measuring station. The measuring stations are linked to the Central Unit - installed in AIA's offices - through modems.

In the Central Unit, data management (e.g., data validation, storage, processing, presentation, etc.) occurs.

The Central Unit is connected through the AIA Local Area Network (LAN) to several Work Stations. The system infrastructure is illustrated in Figure 3.

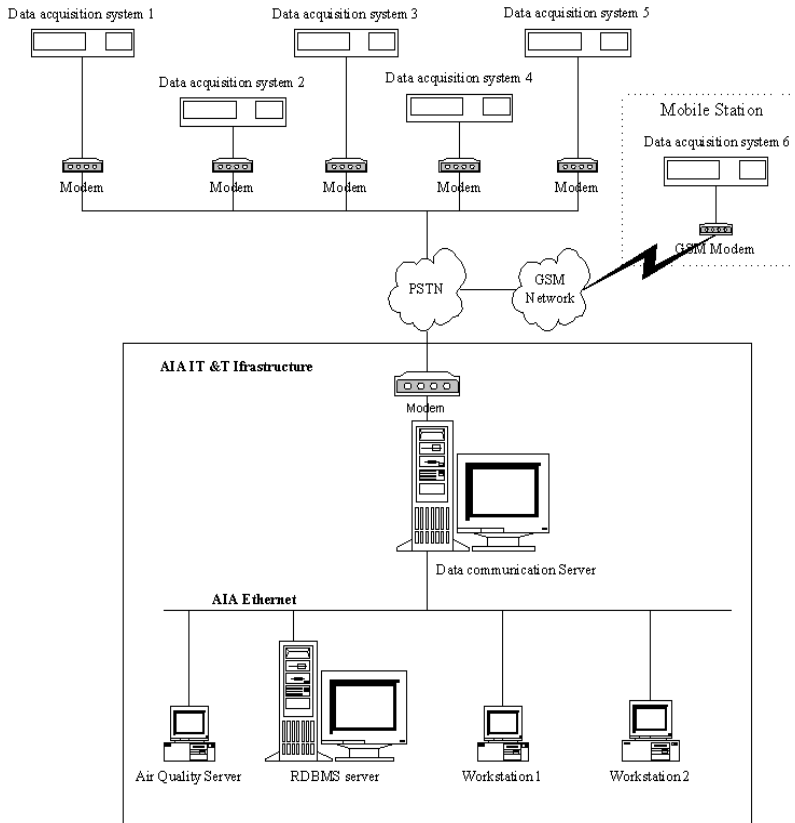


Figure 3: RE 3: AQMN infrastructure and data flow.



2.4 Creation of a high quality dataset

Within the context of the agreement for the provision of consultancy services, the University of Athens (Department of Applied Physics) created a structured database based on the air quality data collected by the AQMN, which was implemented in Oracle [3]. In this database, the necessary programming was performed in the form of “routines” in order to achieve the quality control of the raw data, based on scientific criteria, as described below. After this procedure, a high quality data set is created and the data extracted are in a format suitable for Microsoft Excel in order to perform statistical analysis of the high quality data set and construction of statistical tables on a monthly, semi-annual and annual basis.

More specifically, the quality control of the raw data includes:

- Removal of data that derive: a) from integration of values with capture less than 50% within the interval of half an hour b) during calibration or normal maintenance procedure of the instruments.
- Removal of negative values concerning the air pollutant concentration, relative humidity, wind speed and direction.
- Identification of outliers that are below/above the lower/upper threshold value that the manufacturer provides for the instrument. When such values appear individually without continuity in the following measurements, they are replaced by the lower or upper threshold accordingly. In all other cases, they are removed.
- Identification of unusually high values of air pollutants concentration for short intervals without exhibiting continuity with previous or following values. On the basis of the statistical criterion, these values are defined as greater than [monthly average + 4 times the standard deviation], in order to limit the number of lost data [4, 5]. However, since these values cannot be considered false a priori, rather being related to a local temporary source that acts near the station, they are removed only when they appear in the time-series of a specific pollutant, while the measurements of the other pollutants for the same interval and the same station do not present similar behaviour.
- Identification of unusually low values of pollutant concentrations for short intervals without exhibiting continuity with previous or following values, lower than [monthly average – 4 times the standard deviation]. These values might be attributed to temporary bad operation of the analysers for a specific station. Similarly with the large values, the low values are removed only when they are present in the time series of a specific pollutant while the measurements of the other pollutants for the same interval and station do not present similar behaviour.
- Removal of values that are constant or values that present variation of only $\pm 10\%$ in relation to the previous value for a period of five hours (e.g. ten consecutive measurements). The interval of five



hours was selected on the basis of the experience of the scientific group in the operation of meteorological and air pollution monitoring instruments as well as data quality control.

- Filling small gaps in the time series (up to three consecutive missing values). When one value is missing, then this is substituted by the average value of the previous and the following value. When two or three missing values appear then these are substituted gradually by the moving average value respectively, of the three, four or five previous values [6, 7, 8].

After the creation of the new high quality dataset, the data are statistically analysed and the following parameters are estimated on a monthly basis:

- a) average, minimum, maximum, median, mode and percentile
- b) number of values being removed following the above mentioned procedures
- c) number of values being replaced following the above mentioned procedures
- d) number of exceedances of the limits set by the European Union and
- e) data capture (%).

It should be mentioned that the missing values corresponding to periods of calibration and normal maintenance of the instrument are not taken into account in the estimation of the data capture.

2.5 Reporting

Following the analysis of the high quality dataset, several reports are created on a regular basis. Most of these reports are submitted on a semi-annual basis to the Hellenic Ministry for the Environment, Physical Planning and Public Works, which supervises the operation of the AQMN. Reports of exceedances of pollutants' limit values - as defined by National or European Legislation - are submitted monthly and annually. Air quality assessment also constitutes a part of the more comprehensive Environmental Report (covering all of AIA's environmental activities) sent to the Ministry twice a year as well as of the Environmental Bulletin issued annually. Additional reports containing meteorological data are submitted to the Hellenic National Meteorological Service on a semi-annual basis. Recently, two reports were created by the Environmental Department summarising:

- The results of 4 years of monitoring air quality in the Mesogaia area
- The measurement results for the period the mobile station was in Artemis.

3 SODAR

ENC installed an acoustic radar at the airport in June 2002 in order to monitor wind field conditions. The system comprises a Sound Detection and Ranging (SODAR) system, which is an acoustic system for continuous and remote measurements of the three dimensional wind speed and direction as well as



turbulence characteristics in the lower atmosphere that is based on the Doppler phenomenon.

The SODAR consists of an acoustic antenna, an acoustic enclosure, a processing unit and a power supply unit (see Figure 4). In operation, the antenna emits short sound pulses, which are backscattered at temperature inhomogeneities in the air. The antenna then receives the echoed sound pulses and the amplitude and frequency of the backscattered waves are evaluated. The spectra are determined by application of Fast Fourier Transform to the acoustic signals received from the different directions.



Figure 4: The airport's SODAR.

AIA is the first airport in Greece to have a SODAR operating on its premises. Since no other SODARs are operating in the area, data are checked against radiosonde data collected in the Hellenikon area [9]. Although currently in a trial phase, the preliminary data provided by the SODAR shows good agreement with the radiosonde for both wind speed and direction versus height.

4 DOAS

Early in 2003 ENC initiated a tender procedure to install a Differential Optical Absorption Spectroscopy (DOAS) System at the airport. DOAS systems provide accurate, simultaneous measurement of a number of important pollutants including several criteria pollutants and volatile organics such as BTX. The method is based on the analysis of the spectrum of a light source over an optical monitoring path in the atmosphere of a few hundred meters. The detection of a gas concentration is being held along a line of sight between an artificial light source (Xenon lamp) and a detector over a distance up to several hundred meters. These two units are located at a predetermined distance or collocated when a retro-reflector is used. The radiation intensity emitted by the light source is

detected by the detector and is related to the concentration of the chemical substance in the optical path measured by the system. Various atmospheric species will leave their absorption fingerprints in the spectra from which concentrations can be retrieved. Such systems are using either IR or UV spectral sensors in the detection unit and can detect gases at very low concentrations. By combining the measured gas data with wind speed and wind direction using dedicated software, information such as where the pollution sources are located and the strength of the emissions can be calculated.

The DOAS system will be installed at the threshold of one of the airport's runways and NO, NO₂, O₃, SO₂ and BTX will be monitored. It will be accompanied by software for analysis and processing of data. The DOAS system will not only contribute to the assessment of the air quality but also to the identification of aircraft emissions.

5 ENC/AIA activities

AIA takes several measures – in accordance with the European Union regulations and other standards – for the reduction of emissions and the improvement of air quality. These include:

- Promote the use of natural gas, which produces fewer emissions, for heating purposes.
- Implement energy saving programs on the airport site.
- Minimise the use of Auxiliary Power Units (APU).
- Staff transportation to and from the airport with coaches to reduce traffic and emissions.
- Support of public transport use with express lines, which operate on a 24-hour basis as well as the construction of a train station at the airport.



Figure 5: GreenLight Programme Certificate.

Recently AIA became a partner in the European GreenLight Programme [10]. GreenLight is a voluntary programme whereby private and public organisations commit to the European Commission to reducing their energy use for lighting,

thus reducing emissions that are related to the greenhouse effect. The implementation of a series of energy efficient measures in the lighting of the Main and Satellite Terminal Buildings and the Administration Building led to AIA's participation in the program. The measures consist of:

- Use of energy efficient lamps
- Time scheduling of lighting
- Regular maintenance plan

These measures led to energy savings that reached 3.300 MWh in 2003.

6 Conclusions

AIA is very well equipped to monitor air quality at and around the airport. Continuous monitoring and analysis of the data collected is necessary in order to determine the impact of airport operations on the surrounding environment. Furthermore measures for the reduction of emissions are applied. Future work will focus on the development of an aircraft emissions inventory.

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