A NEW WEB - BASED AIR QUALITY FORECASTING AND ENVIRONMENTAL DATA ACQUISITION SYSTEM

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INTRODUCTION

In the present study, the development of a new web-based data acquisition, information dissemination and air quality data management system in a heavy industrialized area in West Macedonia in Greece is described. The system has been initially developed for online use, giving the concentrations of PM10, PM2.5, SO_2, NO_X, O_3, CO, as well as meteorological data (temperature, humidity, solar radiation, wind speed and direction).

North-western part of Greece is a heavy industrialized area, which is characterized by complex topography. Lignite power stations operate in the area with a total installed generating capacity of more than 4 GW. The main industrial activity is developed in the axis Amyntaio- Ptolemais - Kozani, while relatively recently it has been extended northern, in the region of Florina. The power stations use raw lignite as fuel that is mined in the near by open-pit-mines and is transported in the power stations by trucks, wagons and conveyor belts. The most important environmental problem in the region regarding air quality is suspended particulate matter (*A.G. Triantafyllou et al.*, 2006a).

In order to deal more efficiently with the needs of the area a new web based dynamic ambient air quality data management system for West Macedonia, Greece, has been designed and was given the name EAP-1 (*A.G. Triantafyllou et al.*, 2006b). This was a new data dissemination approach based on a combination of data processing techniques, software and hardware for the manipulation of real time environmental information. It has been developed and operated by the lab of Atmospheric Pollution and Environmental Physics (LAP-EP).

It is a remote air quality data acquisition and monitoring system for real time data collection from a network of stations, data analysis and presentation. The system supplies the local community with a better awareness on air quality around the area in a simple and comprehensible way by using environmental indices. The Air Quality Index AQI (EPA, 1997), Air Pollution Index API (EC, 2000) and Discomfort Index (DI) were calculated and provided together with the previous day's values for comparison. The present web based system is designed with no restrictions regarding the area and the number of monitoring stations that can be included in the network. Improvement of the system is carried out continuously by extending its abilities, i.e. the background concentrations, calculation of relative bioclimatic index, next day expected situation and advice for the protection of the public, other transmittance techniques. This inevitably employs a modelling procedure in a real-time mode. For example the National Oceanic and Atmospheric Administration (NOAA), in partnership with the United States Environmental Protection Agency (EPA), are developing an operational, nationwide Air Quality Forecasting (AQF) system. An experimental phase of this program, which couples NOAA's Eta meteorological model with EPA's Community Multiscale Air Quality (CMAQ) model, began operation in June of 2004 and has been providing forecasts over the northeastern United States (*B. Eder et al.*, 2006).

The Air Pollution Model (TAPM) has been calibrated for the area in a recent study (*S. Zoras et al.*, 2007) and used in a variety of studies (*S. Zoras et al.*, 2006). Generally, the development and deployment of a real-time numerical air quality prediction system is technically challenging (*J.N. McHenry et al.*, 2004). This is even more challenging in complex terrain (*J. Vaughan et al.*, 2004) like the area under consideration. TAPM has started operating beginning of 2007 giving 24 hour AQI and API prediction and pollutants trajectories. Means of telematics, modelling and web based applications are employed and applied in an operational mode. In specific, it is here presented the evolution of the web-based system EAP-1 to EAP-2. EAP-2 employs a novel combination of simulation tools for air quality assessment and next day forecast. New environmental data measuring stations are linked up with the central system via aerial transmission, phone line and mobile connection. The system has been developed for online use, giving the pollutant's concentrations AQI that recently replaced by the API in real-time mode. Present and next day forecast is also available online (http://www.airlab.edu.gr) and on cell phones.

EVOLUTION OF THE WEB-BASED ENVIRONMENTAL INFORMATION SYSTEM
Background
The development of a data acquisition system (http://airlab.teikoz.gr) started as a first attempt in 2002 to establish a web-based information system away from the main Greek cities of Athens and Thessaloniki. The system was designed, with a suitably designed web page, that had the ability of giving real time results of measurements of air pollution and meteorological parameters that depict the atmospheric conditions in the capitals of the four prefectures of West Macedonia as well as at the Technological Education Institute (TEI) where the central operating equipment is located. Other data acquisition systems have been developed and applied around the globe (UK Air Quality Archive: http://www.airquality.co.uk/ ; AIRQUIS: http://www.nilu.no/airquis/ ; DR DAS: http://www.dr-das.com/).

The experimental measurements included concentrations of particulate matter with an aerodynamic diameter less than 10 µm (PM10) and 2.5 µm (PM2.5), sulfur dioxide (SO_2), nitrogen oxides (NO_x), ozone (O_3), carbon monoxide (CO), temperature, relative humidity, solar radiation (total, UVA and UVB), wind speed and direction. The display referred to tables that give the quality limits of the European Union (EU) for each gas pollutant that is measured. Simultaneously, aiming at enhanced comprehension by the wider public, the information was simplified by the use of air quality and bioclimatic indices. Specifically, from the measured concentrations, the AQI depicted on the display by suitable chromatic scales. Based on the temperature and humidity values the DI was also calculated and displayed descriptively. The DI was determined from the temperature and humidity values.

The system was given the code name EAP-1. It covered the capitals of the four prefectures in the area, where measurements were taken during the period June 2002 to July 2004, in a project that was initiated by the Regional Authority of West Macedonia in order to estimate the air quality levels in the greater area. (*A.G. Triantafyllou et. al.*, 2006b). Nowadays, the system operates for the city of Kozani, the local station at TEI, TEI Hill, Kozani airport and Amyntaion. Note that, the system can accommodate unlimited number of network stations.

System Evolution
Local authorities that deal with the civilians' queries are in collaboration with the development team in order to improve and assess the environmental information provided to the public. Scientists and managers, also provide the team with feedback, through the use of the information provided by the web page in regional atmospheric pollution projects. Students

have also used the real time information system, from all over Greece, in carrying out assignments and dissertations with real experimental data (surface meteorology and pollutants). These included data analysis and air quality assessment, air pollution modelling and GIS applications.

API has replaced the AQI in the latest version EAP-2 as is applied in the United Kingdom Air Quality Archive (http://www.airquality.co.uk). This gives in a chromatic scale the air pollution bandings and index and the impact on the health of people. More meteorological and pollution sampling stations have also been linked up with the system. These are the TEI hill where meteorological data are transferred via a mobile connection, Kozani airport via phone line and Amyntaion in the north via aerial transmission.

The Air Pollution Model (TAPM http://www.dar.csiro.au/TAPM) is a PC-based, nestable, prognostic meteorological and air pollution model that solves fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentration. TAPM has been employed in a real-time operational mode to give next day weather forecast, PM10 daily average concentration and API indexes. Five day forecast of synoptic data are downloaded every morning on a PC hard drive from SKIRON modelling system (http://forecast.uoa.gr). This is a weather forecasting system initially developed for the Hellenic Meteorological Service and now being in operational use in 17 other sites worldwide. It is based on the Eta/NCEP model. It is in operational use at the University of Athens with over 7000 visitors per day. The downloaded synoptic data are then read by a FORTRAN code and converted to the format required by TAPM. The model runs and finally, a few batch files upload results to the server. The whole process is integrated into a visual basic executable file.

Building blocks of the two main cities in the area (i.e. Kozani and Ptolemais) are imported to TAPM to accommodate urban emission sources. Traffic emissions were calculated from the experimental number and type of vehicles according to the European Guidelines (EEA, 2003). GPS measurements have been carried out of the urban street canyon locations and imported into TAPM as area pollution sources. Field measurements in the area (*A.G. Triantafyllou et al.*, 2006a) have been employed to validate emissions form stacks and mining operations i.e. particulate matter, SO_2, NO_x and smog.

The mean daily PM10 concentrations during a 30 day period (April 2007) have been taken under consideration to prove TAPM's high degree of reliability. The hourly sampling coverage reached about 90% during the 30 day period. The RMSE between the next day forecasts and measurements was about 9 $\mu g/m^3$ while API indexes have been predicted in about 100% accuracy. Obviously, this was due to the nature of these indexes that range in relatively wide intervals. However, this still remains of paramount importance in regional environmental data dissemination, decision making systems, public awareness and protection. Minimum and maximum temperatures were also predicted with a high degree of accuracy with a root mean square error less than one degree. Actually, this was presumable if someone considers that the model's calibration (*S. Zoras, et al.*, 2007) was sufficient. In addition, all input data are derived from real experiments in the area e.g. number of vehicles, building blocks. It was also, of paramount importance, the knowledge acquired from past experimental data to set the background values of pollution (*A.G. Triantafyllou et al.*, 2006a).

Implementation of the new information system
The monitoring stations are equipped with sampling and meteorology instrumentation. Specially developed software stores all experimental data locally at every station before it is

downloaded from the primary web server at LAP-EP via modem or mobile connection or aerial transmission. The user is provided with a clickable sketch of the network in the region for the selection of a particular location (Figure 1). For each station a new HTML file is produced which shows the station name together with the measurements and processed results. The API indexes are given analytically for each location. This includes the values of the previous day; today and tomorrow (see Figure 2). The full forecast is available online via the web (see Figure 3) and a less detailed one on cell phones via a text message centre.
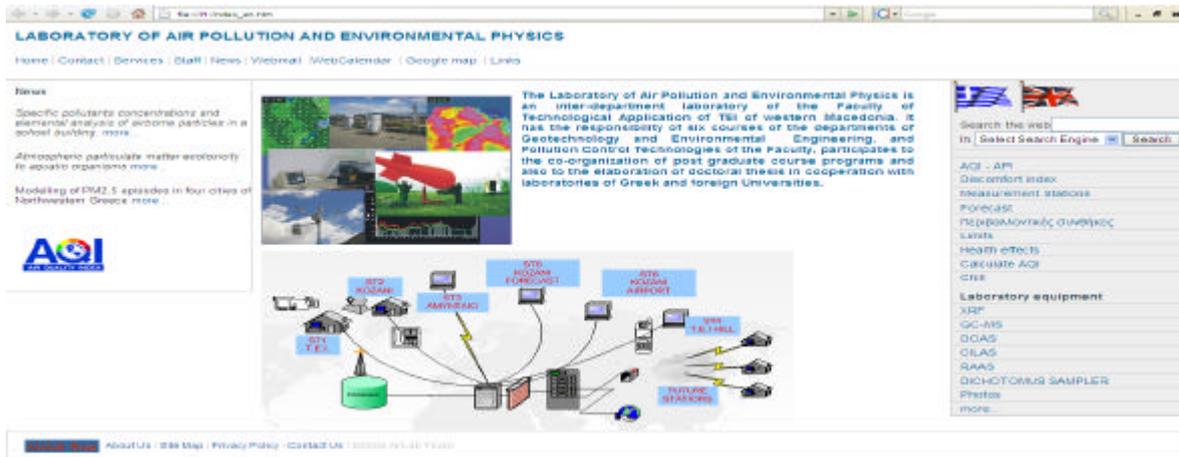

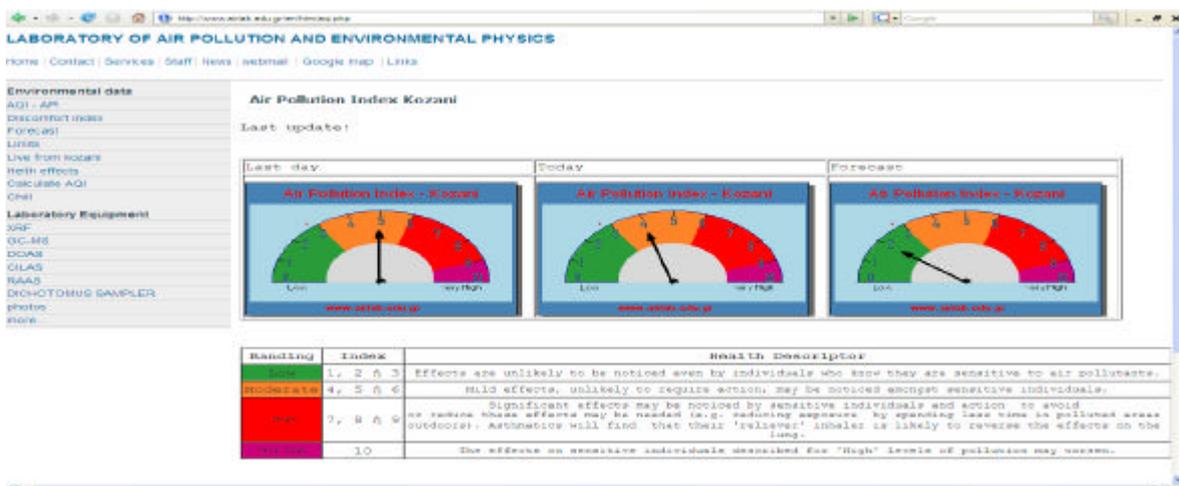*Fig. 1; Home page of the web-based environmental data and forecasting system*

Fig. 2; Values of API indexes for a specific location and chromatic explanation

Fig. 3; Forecast for Kozani site

CONCLUSION

The mesoscale model TAPM has been integrated in a new web-based dynamic ambient air quality data management system (EAP-2) designed for West Macedonia, Greece. Forecast results were really promising in terms of API and weather accuracy. In the framework of the present study, it was also revealed the importance of experimental pollution data in emissions validation. The developed system is a novel operational forecasting system in terms of the combined tools that remotely acquires environmental data, predicts and disseminates processed air quality information via the web and cell phones. The present web based system is designed with no restrictions regarding the area, the number of monitoring stations that can be included in the network and kind of connection. It can accommodate phone line, aerial transmission and mobile data transfer. Note that, maybe the most important advantage of the system is that all network, database and forecasting processes are designed to work on a single PC. Meaning that operational and resource costs are low. This work was to extend the system's abilities in terms of advice given and the protection of the public under a future decision making system. Issues of air quality management systems in terms of information dissemination and decision making would include a format understandable by the public, local authorities and managers to aid them in the understanding of the relevant issues.

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