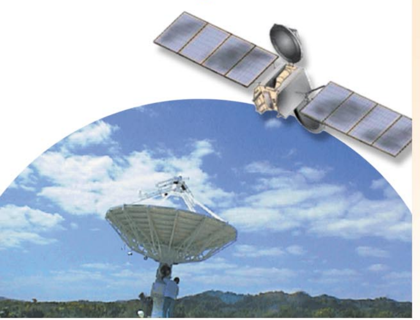


SATELLITE-ASSISTED MANAGEMENT of Air Quality

www.smaq-life.org

With the contribution of the LIFE financial instrument of the European Community and the Prefecture of Florina

SMAQ AN INTEGRATED SYSTEM FOR ATMOSPHERIC POLLUTION MANAGEMENT

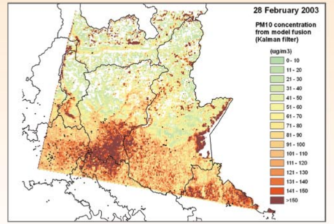
Recent studies worldwide have revealed the relation between urban air pollution -particularly fine aerosols- and human health. This, in turn, has created a pressing request from both environmental scientists and decision-makers for spatial, timely and comparable information on air pollution and associated indicators. Particles in the size range 0.1–3 μm are considered to be amongst the most important with regard to adverse health effects.

Current problems with air pollution monitoring are linked to the high costs of extensive and continuous measurement of atmospheric pollutants in a changing chemical composition of the lower atmosphere, which results in changing requirements for monitoring systems. An additional problem linked to this inherent difficulty is the increasing need for source apportionment of pollution in order to optimize environmental management aiming at abating the pollutant emission intensity via technology improvements and mitigating their effects on human and ecosystem health by limiting human exposure. International and national legislation regulates the monitoring and management or primary pollutants such as SO_2, NO_x, O_3, total suspended particles (TSP) as well as greenhouse gas emissions since the last 10-20 years. Regulation on the ambient air concentrations of pollutants such as volatile organic compounds (VOCs), benzene and particulate matter (both coarse and fine) has been introduced at the EU level only during the last 5-6 years. This has created the need for extending the air quality monitoring networks put in place to check regulatory compliance in each EU member state to include the "new" pollutants mentioned above. The continuously rising cost of running air quality monitoring networks has slowed down the implementation of the relevant legislation and puts under pressure competent authorities across the European Union and the USA.

Atmospheric aerosol may act as a driver for enhancing the global warming potential of an area through local perturbations to the regional radiation balance and increasing the radiative forcing of the atmosphere. Therefore, accurate estimation of the aerosol loading in the lower troposphere would contribute to the improvement of our understanding of the link between urban/regional pollution and global climate change.

To date ground measurements of particulate matter are not taken from dense enough monitoring networks around the world to permit a satisfactory analysis of the actual influence of fine urban aerosol on the health of vulnerable population groups, such as the elderly, children under the age of fifteen, asthmatics, people with cardiovascular problems. Recent attempts to improve our estimation of fine aerosol concentrations at the urban and regional scale from combining ground data with numerical modeling are hampered by the need for high quality and up-to-date emissions inventories, as well as for accurate estimates of initial and boundary conditions of the models. This information is not always available in many cities around the world. Satellite-derived information has been considered a possible solution to this impasse. Satellite data, however, although producing environmental data at various geographical scales (from 0.5 m to 10 km of resolution) are time-deficient due to generally long periods of revolution around the Earth.

Example of result of the methodology followed in SMAQ in Lombardy, northern Italy



Map of ambient air concentration of fine particulate matter (PM10) [μg/m³]

In line with the European legislation

The need for accurate assessment of the atmospheric pollution loading in European regions in order to comply with the EU regulation on atmospheric pollution as expressed by the Framework Directive 96/62/EC on ambient air quality and its daughter directives becomes all the more pressing in view of two recent policy developments at the Community level:

(a) the Environment and Health Action Plan, which calls for an integrated approach to assessing and mitigating the adverse effects of environmental stressors (including airborne pollutants) on human health; and

(b) the EU strategy for countering climate change, which has identified the need to shed light in the link between atmospheric pollution at the local and regional level and radiative forcing of the atmosphere at the global scale.

These two new elements in combination with the drive towards completing the Thematic Strategy for Air Pollution (expected to reach finalisation in 2006) make the need for an objective and scientifically rigorous method for air pollution assessment that would be at the origin of cost-effective pollution abatement strategies a necessity in today's Europe.

Atmospheric Pollution and Health

The World Health Organisation (WHO) reported in 2002 that approximately 25-33% of the total burden of disease in industrialized countries can be attributed to environmental factors. The major part of the environmental health burden affects children, the elderly and other vulnerable groups. Large proportions of deaths and DALYs (Disability Adjusted Life Years) in European children are attributable to outdoor and indoor air pollution, inadequate water and sanitation, lead exposure, and injuries. Interventions aimed at reducing children's exposure to environmental factors and injuries could result in substantial gains. The pronounced differences by subregion of Europe and age indicate the need for targeted action that takes into account spatial and temporal differences in human exposure to environmental toxicants and stressors. The burden of disease was much higher in Eastern and Southeastern Europe than in the EU-5. Although the data collection capacity has been rising steadily over the last decade, there is still substantial uncertainty around some of the estimates, especially for outdoor air pollution.

With respect to exploring the health burden of air pollution in Europe, the APHEA (Air Pollution and Health: a European Approach) studies have provided much insight. The APHEA-2 mortality study covered a population of more than 43 million people living in 29 European cities, which were all studied for more than 5 years in the early-mid 1990s. From data involving 21 cities, the combined effect estimate showed that all cause daily mortality increased by 0.6% (0.4–0.8) for each 10 μg/m³ increase in PM10. The APHEA-2 hospital admission study covered a population of admissions for asthma and chronic obstructive pulmonary disease (COPD) among people older than 65 years were increased by 1.0% (0.4–1.5) per 10 μg/m³ PM10, and admissions for cardiovascular disease (CVD) were increased by about 0.5% (0.2–0.8) per 10 μg/m³ PM10 and by about 1.1% (0.4–1.8) per 10 μg/m³ black smoke.

The area of Western Macedonia in northern Greece is particularly loaded by atmospheric pollution mainly due to the existence of the main thermal power plants in the country and the valley-type orography. The air quality monitoring station in Ptolemais, the main location affected by fossil fuel pollution reached 380 μg/m³; the no concern level for outdoor concentration of fine particles is 50 μg/m³.

How SMAQ will work

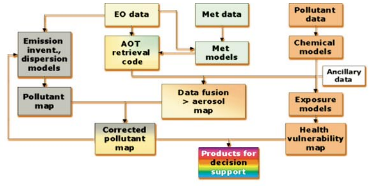
Earth observation (EO) data provide direct information on an air quality indicator, namely atmospheric turbidity, as measured by the optical thickness of the aerosol layer in the atmosphere. Furthermore, EO would give information on land use/cover including seasonal changes (e.g. snow coverage and surface albedo) and the landscape of the area of interest through the creation of digital elevation models (DEM). The profiles of aerosol optical thickness derived from EO refer to the total atmospheric column. It is reasonable to assume, however, that the majority of the pollutants of interest for air quality assessment remain within an atmospheric layer that spans from the ground till the mixing height in the atmosphere. Mixing height is calculated from meteorological data, based either on observation data or on meteorological models such as CALMET. This information will then be used to correct the optical thickness values derived from EO image processing and calculate the scattering coefficient of aerosol.

Ground-based air quality measurements (coming from the fixed monitoring network and/or from ad hoc experimental campaigns) are stored in an air quality database. These data serve as input to a chemical model used for the transformation of primary pollutants such as NO_x and SO_2 into secondary aerosol. Through this process and measurements of PM10 and PM2.5, the amount of atmospheric aerosol and the chemical species comprising it are calculated and a statistical model correlates the scattering coefficient of aerosol (derived from satellite data) to its mass. **Fine particulate and other pollutant maps** of the area of interest can be produced from this correlation. The maps will be completed with the help of an ad hoc campaign employing biosensors to estimate both the spatial distribution of pollution and its effect on ecosystem health.

The maps will be visualised either locally at the TEI of Western Macedonia or, via the Internet Map Server, through the Web site of the local authority responsible for local/regional atmospheric pollution. In addition, **health impact indicator maps** will be created by applying exposure-response functions to the atmospheric pollution data taking into account the population density distribution in the area of interest.

On the basis of these results, and taking into account a techno-economic analysis of the main polluting activities in the area of Western Macedonia, optimised scenarios for pollution abatement and for reduction of human exposure to air pollutants will be developed with a target to lead to a significant reduction of the air quality burden on human health in the area.

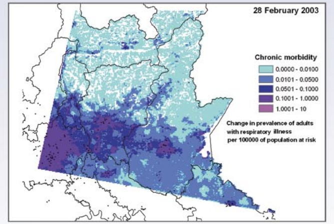
The ICAROS data fusion method at the core of SMAQ



The proposed system includes:

1. A station for receiving satellite data covering an area of 100 km radius.
2. A unit for receiving and processing meteorological and air pollution data from ground stations.
3. A unit for interpretation and processing of data so that they can be received in an appropriate format by the central unit istalled at the TEI of Western Macedonia.
4. A pollution mapping unit using a Geographic Information System (GIS) for mapping the risk and producing tables of risk data for the population and the ecosystems.

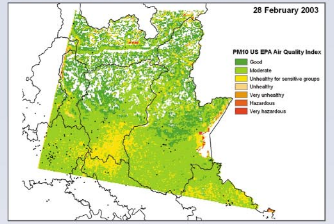
Example of results on potential health impacts due to air pollution in Lombardy



Map of Chronic Morbidity due to ambient air particulate matter (PM10)

The system will be capable of receiving, evaluating and integrating all other data originating from ground station measurements (Public Electricity Corporation, Ministry of the Environment, Land Planning and Public Works, Local Authorities Organisations, Educational Institutions etc.). It will be also capable of correlating these data with satellite data so that a comprehensive picture of atmospheric pollution in the area will be generated. Moreover, the system will be capable to propose modifications in the ground measurement network(s) to ensure the reliability and comprehensiveness of the information.

Example of Air Quality Index map of Lombardy, estimated with a method employed in SMAQ



Map of Air Quality Index

The EU Programme LIFE – ENVIRONMENT will offer the possibility:

1. To perform, for the first time, an integrated evaluation of an existing situation as far as emissions are concerned, using existing data.
2. To provide to the Local Authorities a tool for the early warning of the population and/or the prevention of pollution incidents.
3. To indicate to the PPC measures in order to reduce pollution at the source and/or to elaborate scenarios for improving the existing situation, or to adopte alternative solutions in the domains of mining, energy, and pollution abatement.

4. To acquire immediate information on the exposure of the population to pollution by using direct measurements on the individuals scale (by using portable counters and taking a representative sample).
5. To carry out demonstration activities of pollution abatement (NO_x) inside buildings (residential or business) by applying the method of photo-catalysis.
6. To enhance knowledge and information concerning pollution by using bio-indicators.
7. To assess impacts of pollution on flora and cultivations, so that the appropriate measures are taken and the necessary adaptations are made in a subsequent phase.

Standardisation and technology export

In addition to the implementation of the project in the area of Western Macedonia (Greece), there will be two pilot demonstration implementations in the region of Veneto (Italy) and Budapest (Hungary). These implementations aim at the standardisation of the project and the examination of the possibilities of extending it in other Member States and regions in the EU.

Some economic data....

The installation of the monitoring system to be developed in the framework of the SMAQ programme and its operation for a ten year period will cost €100.000 per year, ie. four times less than a ground based network of stations, with comparable capabilities, which would cost €415.000.

It is estimated that the implementation of SMAQ will lead to a 20% reduction of air pollution in the area. It is estimated also that the reduction of air pollution by 20% in the area, the economic benefit from the reduction of medical costs and the extension of life expectancy in the local population might be € 756.000 per year.

The innovation introduced by the project ...

- Use of satellite pictures that offer a comprehensive, accurate, objective and high resolution picure of air pollution in the entire area.
- Comparison of satellite pictures and measurements of air pollutants at ground stations.
- Possibility of system optimalisation and improved spatial distribution of the network of ground stations taking account of the available resources and the existing needs.
- Integrated assessment of air pollution on public health, taking account the demographic-spatial analysis.

... and its advantages compared with other methods

- The system is based on the best available technology for assessment and monitoring of air pollution.
- It can be used and extended in other regions with similar problems and features.
- It assesses automatically the impacts of air pollution on human health.
- It has lower operation costs in comparison with the best conventional systems for monitoring and management of air pollution.

THE SMAQ-PARTNERS

TEI
Technological Education Institute of West Macedonia
Koila - Kozanis, Kozani 50 100 GREECE, P.O. Box 293
Tel: +30 24610 68015-2, Fax: +30 24610 39682
e-mail: eamanatidou@kozani.teikoz.gr, www.teikoz.gr

DIPE
Interdisciplinary Institute for Environmental Research
Saripolou 11, Athens 106 82, GREECE
Tel: +30 210 8848055-6, Fax: +30 210 8846278
e-mail: dipe@otenet.gr, www.dipe.gr

KEPE
Purely Prefectorial Enterprise of Kozani
"Environmental Centre"
1st Km Ptolemais-Kozani, Ptolemais 502 00,
GREECE, P.O. Box 65
Tel: +30 24630 53571, Fax: +30 24630 53666
e-mail: info@kepekozani.gr, www.kepekozani.gr

CERTH/CPERI
Centre for Research and Technology Hellas /
Chemical Process Engineering Research Institute
6th Km Charilaou-Thermi Road, GR- 570 01, Thermi
Thessaloniki, GREECE, P.O. BOX 361
Tel: +30 2310 498100, Fax: +30 2310 498180
e-mail: karabaj@cperi.certh.gr, www.cperi.certh.gr

REC
Regional Environmental Center for Central and Eastern Europe Department: Business and Environment Programme
Ady Endre ut 9-11, Szentendre H-2000, HUNGARY
Tel: +36 26504 000, Fax: +36 26504 008
e-mail: rnemeskeri@rec.org, www.rec.org

AUTH
Aristotle University of Thessaloniki,
School of Biology, Department of Ecology
University Campus, Thessaloniki 541 24,
GREECE, P.O. Box 119
Tel: +30 2310 998251, Fax: +30 2310 998376
e-mail: jdiamant@bio.auth.gr, www.auth.gr

ORIZON
K. Anagnostopoulos - K. Papanikolaou & Associates P.Co.-ORIZON P.Co.
Halandriou 16 & Souliou, Agia Paraskevi 153 43, GREECE
Tel: +30 210 6009006, Fax: +30 210 6005851
e-mail: orizonoe@otenet.gr

JRC
Joint Research Centre - Institute for Health and Consumer Protection Physical and Chemical Exposure Unit
Via Enrico Fermi 1, Ispra (VARESE) 210 20, ITALY
Tel: +39 0332 785373, Fax: +39 0332 789963
e-mail: alberto.gotti@jrc.it, www.jrc.cec.eu.int/pce

www.smaq-life.org

Production: Interdisciplinary Institute for Environmental Research (DIPE)
Text: Ilias Efthymiopoulos, Alexandra Meliadou, Denis Sarigiannis (JRC)
Scientific Responsible: Denis Sarigiannis (JRC)
Editor: Prokopis Gavriil
Art Direction: Pavlina Alexandopoulou
The publication was financed by the LIFE-ENVIRONMENT Project (LIFE05/ENV/GR/00024)