HEalth Risk from Environmental Pollution Levels in Urban Systems

**Reporting**

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HEREPLUS binds together four universities (Rome-Sapienza, Dresden, Belgrade, Keele), five research organisations (Joint Research Centre (JRC), Academy of Athens, CIEMAT, CNR, ISCIII) and one technology structure (Sapienza Innovazione). Partners are located in six countries (Italy, Germany, Spain, Greece, the Russian Federation and United Kingdom (UK)).

The main activities and results can be summarized as follows:

- Review of the scientific literature on methods used to monitor the link between air pollution and health and environmental data. The results have been used to frame and underpin data collection and analysis, and for developing air pollution, vegetation and epidemiological models.
- Integrated databases, arranged on a geographical basis for each of the four cities, and covering the period 2003-2005 with climatic and pollution data, individual epidemiological data (mortality and morbidity potentially associated to O3 and PM pollution), the distribution and covered area of urban parks and gardens, eco-physiological data of the main woody species representing the urban vegetation. The databases have a relational structure, and contain geo-referenced data.
- Modeling simulations of the response of human health to O3 and PM concentrations, encompassing both collating the best available epidemiologically-derived concentration-response models, and adapting existing models to local situations (sanitary districts).
- Modeling simulations of O3 and PM uptake / deposition dynamics by woody vegetation in the different conditions. The daily amount of O3 and PM10 depositions to urban vegetation of Rome and Madrid have been estimated, by applying the MOCA-Flux and Chimere models, which have been parameterized by local vegetation data (geographic position, structure and function of the main woody species).
- Production of distribution maps of O3, PM10 in each of the studied cities, by using geo-statistical approaches, atmospheric modeling or a combination of both.
- Quantification of the removal role of urban vegetation on O3 and PM10 pollution levels, in a spatially resolved form, on the basis of the O3 and PM10 distribution maps. Moreover, the air quality improvement due to vegetation sink capacity for O3 and PM10 of large urban parks such as Villa Ada in Rome, El Pardo Madrid, Lofos Lycabettus and Parko Aeroporikis Vasis Ellinikou in Athens, has been also quantified.
- Production and validation of integrated health risk maps, in GIS environment, for both cardiovascular and respiratory deaths and hospitalizations. In particular, from the pollutants concentration maps and the calculated attributable fraction (AF) of exposed populations, quarterly maps of the estimated absolute number of cases were produced in the four studied cities, for each epidemiological end-off.
- Development of an operational manual, containing guidelines for establishing urban-environmental measures to minimise the health costs associated to outdoor air pollution. The guidelines are addressed to local and national Stakeholders such as urban green managers, air quality managers, mobility managers. The best practice recommendations included in the manual cover the improvement of air quality monitoring networks based on a better assessment of the spatial extent of urban air pollution and its impacts on public health, and optimal use of urban green to enhance its pollution sinking capacity, respecting the local climatic and environmental conditions, and including land use planning considerations.
- Study of applicability of the developed methodology to other urban areas, to facilitate the transfer and implementation of HEREPLUS results within any urban hotspot experiencing environment and health concerns. The findings are intended to help standardize HEREPLUS to facilitate its transfer primarily - although not exclusively - to Member State regions.
- Involvement of stakeholders, which participated the meetings and confirmed their interest in applying project outputs to the to the routine management practice of urban quality policies.

Project context and objectives:

Human activities in urban conurbations are inevitably concentrated in a relatively small area. Most economic activities involving the use and conversion of energy are accompanied by emissions of air pollutants, thereby degrading the environment, particularly the urban environment. Urban air pollution is the cause of numerous problems, including most importantly health risks through the inhalation of gases and particles. A consensus has been emerging among public health experts that air pollution, even at current ambient levels, aggravates morbidity (especially respiratory and cardiovascular diseases) and leads to premature mortality. This is based on the past decade's epidemiological studies in Europe and worldwide which have measured increases both in mortality and morbidity associated with air pollution. In this sense, air pollution presents a serious threat to human health and well-being of citizens which in turn lead to an increased interest in the scientific / policy interface in developing tools for assessing and quantifying the impact on health of local population.

In Europe, from a legislative perspective health protection across all public policies emerged as a common health policy theme (WHO, 2005). Two different treaties, Maastricht Treaty (1993) and Amsterdam Treaty (1999), are concerned with health protection in the broader sense. Article 129 of the Maastricht Treaty explicitly stated that 'health protection shall form a constituent part of the Community's other policies', while article 152 of the Amsterdam Treaty has claimed for a 'high level of human health protection (to) be ensured in the definition and implementation of all community policies'.

In EU countries, environmental impact assessment has been implemented as part of planning control, with the implementation of Directives 85/337/EEC, 97/11/EC, and the Air Quality Directive (2008/50/EC). Guidelines for health impact assessment have been produced in several countries. As far as air pollution impact on population health, very few examples exist. The methodology used in the CLEAN AIR FOR EUROPE initiative of the European Commission (EC) draws on time series studies that examine the relation between daily levels of air pollution and the risk of adverse health effects, on the same day or subsequent days. A World Health Organization (WHO) working group additionally linked evidence of long term effects of exposure to PM10 on total mortality and chronic bronchitis from cohort studies with population data from Austria, France, and Switzerland.

During the past three decades, more and more research findings have pointed to urban green spaces as a resource in promoting public health. It has been suggested that green spaces promote health by restoring mental fatigue, serving as a resource for physical activities, and reducing all-cause and cause-specific mortality. Furthermore, the presence of green spaces in the neighborhood may lead to lower personal air pollution exposures because of lower average air pollution concentrations in the neighborhood and / or more time spent in green space that might be associated with lower average air pollution concentrations
resulting in positive health effects.

Urban greening is known to be one approach to mitigate the human health consequences of increased temperatures resulting from climate change, in combination to the overall effect of the urban infrastructure. Despite the increasing interest in the scientific community in assessing the potential benefit of green areas on human health, there is currently very little empirical evidence to quantify these relevant pathways or actually to assess how much they play a role.

In the above context HEREPLUS project has been thought and carried out to fill some of the identified gaps in the evidence base and develop and apply an integrated methodology for assessing and quantifying the health risk associated to outdoor pollution exposure and for investigating the potential mitigating role of urban green. The final objective of the project is the provision of guidelines for urban managers and administrators responsible for urban environmental management measures aiming at minimising the health cost of urban air pollution.

More in detail, the common methodology developed has been applied in four demonstration cities in the European Union (EU) (Rome, Athens, Madrid and Dresden) and it was based on the following:

1) Development of methodologies to improve the knowledge about the exposure to outdoor air pollution levels of ozone and particulate matter through the application of different and innovative techniques both geo-statistical and based on satellite-derived information in order to enhance the spatial resolution of the concentration field, which represents a major weaknesses of any exposure assessment.

2) Collection and processing of time series of epidemiological data (morbidity and mortality) with the aim of developing and validating new exposure-response functions for respiratory and cardiovascular health outcomes in the four aforementioned cities. To obtain new E-R functions, these epidemiological data have been processed following the classical epidemiological approach based on Poisson statistics as well as developing innovative approaches making use of artificial neural network techniques.

3) Development and application of spatial epidemiology methods to obtain high resolution maps of morbidity and mortality indices with the objective of providing a powerful aid to the analysis and understanding of the relationships between geography, the environment, and human health. To this aim, the WHO guideline for air pollution (2005) was followed. That is based on the concept of attributable proportion, indicating the fraction of the health outcome, which can be attributed to the exposure in a given population.

4) Improvement of the knowledge of the potential role of different urban vegetation types for mitigating the O3 and PM pollution levels, and provide best practices regarding the selection of no-VOCs emitting species and management of large green areas located in different neighboring urban areas.

Project results:

The main results are summarised as follows:

1) Databases set-up

HEREPLUS databases include, for each of the studied cities (Rome, Madrid, Athens, Dresden) the
following data:

- available datasets on meteorology;
- available datasets on pollution;
- available datasets on epidemiology;
- available datasets on vegetation distribution and eco-physiology;
- other available GIS datasets relevant to HEREPLUS objective (socio-demographic, traffic load, digital terrain / landscape model).

The databases were implemented in Microsoft Access® software, in order to grant interoperability in data storage, management and exchange, internally to the network of project participants. All data structures are relational, i.e. the data tables are linked to each other by means of univocal identifiers of records (IDs). In this way, each record can be easily accessed and shared by different tables. All data are geo-referenced at UTM33N WGS84, by specifying the geographic coordinates of each single observation, both for point-form and for polygonal spatial information. As such they were ready to be analyzed by GIS technology.

Database production was based on the following steps:

1. Collection of available datasets for each type of data (climate and pollution, epidemiology related to air pollutant, urban vegetation distribution and coverage, eco-physiological data of the main urban woody species) and for each urban area (Rome, Madrid, Athens, Dresden).
2. Integration of the datasets in order to produce an integrated database for each type of data.
3. Description and development of a relational database scheme.
4. Description of HEREPLUS dataset sharing: a check list of data availability.

All database models and schemas are compliant with the data specification and metadata implementing rules of the 'Infrastructure for spatial information in the European Community' (INSPIRE), established by the EC Parliament Directive 2007/2/EC.

2) Spatial analysis of pollution data

Air pollutants distribution maps (PM10, and ozone) have been produced for the cities of Rome, Madrid, Athens and Dresden within HEREPLUS-WP3. A GIS approach has been used as it allows relating geo-referenced variables and using deterministic and geo-statistical methods to improve estimations. Whenever it has been possible, pollutant distribution maps have been obtained by a combination of statistical or geo-statistical methods and atmospheric models. The period 2003 - 2005 has been selected for this study. Spatial domains and resolution varied among the different areas, depending on the utilized approach and available data. Metrics of the maps have been established in agreement with health criteria: daily maximum eight-hour average for ozone and daily average for PM10.

Spatial analysis of pollution data in Rome

In Rome, maps of estimated pollutant distribution were produced on the basis of pollution observations.
from the air quality stations. Co-kriging algorithms were selected, which allow to use information on accessory data (drift variables, i.e. environmental variables spatially related to pollutant distribution) to improve the interpolation of pollutant estimates in locations where drift variables are measured. Daily ozone maps were produced for the municipality of Rome (about 1285 km2) for the period 1 January - 31 December 2003 and for selected dates in 2004. Daily mean concentration of NOx was used as external drift, as it was measured in a higher number of monitoring sites, thus exploiting the spatial relationship between these two pollutants.

Two different ozone metrics were used to express ozone levels in Rome, as related to health effects and vegetation uptake, respectively. Daily maximum eight hr average was used for coherency with epidemiological modelling to estimate sanitary risks, whereas daily mean concentration averaged over daylight hours was used for coherency with eco-physiological modelling to assess ozone uptake and estimate the mitigating role of urban vegetation. In both cases, high-resolution (30 x 30 m) maps were produced, based on satellite data resolution for land cover and vegetation distribution.

About PM10 maps, notwithstanding the complex pattern over time of this pollutant, the overall spatial variability in the city of Rome, as estimated by the standard deviation of observations from the air quality monitoring stations, is negligible. Thus, interpolation by geo-statistical methods did not provide an adequately effective result, also due to the low spatial density of PM10 monitoring stations. However, examples of quarterly PM10 maps for Rome, produced by kriging method, are provided, in order to evaluate both the excessively low sampling density and the consequently high error of geo-statistical interpolations. For a more detailed assessment of PM10 spatial distribution in the city of Rome, PM10 meta-maps were produced, following the methodological approach reported for Athens.

Spatial analysis of pollution data in Madrid

In Madrid, two different approaches were used for different purposes within HEREPLUS project. Daily maps for ozone and PM10 were produced using a combination of measurements and photochemistry modelling. In this way, the skills of both observations (accuracy) and model (complete coverage) contributed to obtain more realistic concentration maps than using just observations or model predictions. These results were used for the analysis of spatial and time distributions and allowed performing those exercises devoted to assess the effect of land use changes (vegetation) on PM10 and ozone concentrations in the study domain.

For the epidemiological study the Madrid Community, was divided into seven homogeneous areas. These corresponded to the environmental classification established by the Madrid Community government in 2001 and used during the period 2001 - 2006 to fulfil the requirements of the EC/96/62/CE Directive concerning the air quality assessment in the European Member States territory. Each area was then representative of a specific air quality index. This classification was used in HEREPLUS with a minor modification: while in the above mentioned classification, municipality of Madrid is divided in two zones, the northern one assigned to the zone 5 and the southern one assigned to the zone 1, for this project the whole municipality of Madrid was considered as a unique zone (called zone 1). The main reason was related to the spatial resolution for the epidemiological data, in this case the municipality. Thus, this zone (zone 1) was covered by the Madrid municipality network (27 monitoring stations) and the rest of the zones
was covered by the regional network stations (composed by 18 stations distributed as follows: 5 stations in zone 2, 5 stations in zone 3, 2 stations in zone 4, 2 stations in zone 5, 2 stations in zone 6 and 2 stations in zone 7). Daily mean of PM10 and O3 concentration maps were calculated averaging values from different stations in each zone for the period 2003-2005.

Spatial analysis of pollution data in Dresden

Variables which influence the PM10 and O3 concentration were identified as well as the availability of data for the city Dresden and its spatial and temporal resolution. The variables can be divided into spatial base data and spatial thematic data. All variables correspond to a layer in the GIS. The topographical situation is described in detail by the spatial base data. Some of the variables do not relate to the PM10 and O3 concentration. These variables, especially the administrative units, were created as layers and used to optimise the visualisation and orientation in the map. Most data describe parameters in discrete time points.

Deterministic methods such as IDW (Inverse distance weighted) and the geo-statistical methods Kriging and Co-kriging were used for mapping the distribution of air pollution (PM10 and ozone). Thus, in a first step the simple interpolation method IDW was applied. Dresden consisted and consists of two / three measuring stations. It depends on time period that is considered (two stations in 2003 and 2004 and three station in 2005). Stations next to Dresden were involved in the analysis to reach a higher precision of air pollution maps. These stations are located in a radius of 60 kilometres around Dresden and were integrated in the analysis. The measured values were stored in a database. PM10, ozone and temperature values were joined to the point layer containing the measurement stations for an interpolation in the GIS. The calculations were performed with the power of two and the determined values above the bounding box of the measurement station were extrapolated.

Consequently, another method was needed. A modelling process was carried out by the Saxon State Ministry of the Environment and Agriculture and a local engineering office (Lohmeyer Consulting Engineers Karlsruhe and Dresden Germany). This model process consists of four steps and comprises Radial Interpolation, LASAT and Prokas. PM10 concentration was calculated in the spatial resolution of 1x1 km.

An own methodology was developed for mapping. The result is a map as well as a table showing the concentration values in a high temporal and spatial resolution. For the postal code areas a daily value for PM10 and O3-concentration was available for further analyses.

Spatial analysis of pollution data in Athens

In Athens, two methodological approaches were developed and applied to improve the spatial resolution of the pollution concentration fields: the first one makes use of advanced geo-statistical techniques (kriging algorithms) and the second one is based on data fusion methodology used to integrate the three information data sources (i.e. Earth observation (EO), ground-based information and atmospheric modelling) to derive the PM10 pollution loading at the ground level at very high spatial resolution.

Although these two methodologies are independent and can be applied separately, a further
The first mentioned methodology applies advanced geo-statistical techniques to spatially interpolate the pollution levels at an unobserved location from observations of its value at known locations (monitoring stations). After an analysis of possible geo-statistical techniques and on the basis of the data available, kriging algorithms have been selected as the most suitable method to derive the pollution field at the ground level. Average seasonal PM10 and O3 maps were produced for the greater Athens area for the period 1 January - 31 December 2005. PM10 seasonal daily averages maps for Athens in 2005 were obtained averaging on seasonal basis daily concentrations measured at the monitoring stations and then applying kriging algorithms. O3 seasonal daily averages of 8-hrs maximum value maps for Athens in 2005 were obtained averaging on seasonal basis daily eight-hours maximum concentration measured at the monitoring stations and then applying kriging algorithm result (as an example of ozone presentation with this approach).

a) O3

High resolution maps (30 by 30 m) of seasonal daily average of O3 8-hrs maximum values have been produced for the four seasons of 2005. Regarding the seasonal ozone variation, it is observed from the maps that the average ozone concentrations are higher for summer than for winter. This pattern follows in general the corresponding seasonal variations of solar irradiation and temperature as ozone is a secondary photochemical pollutant and the ozone production capacity of the atmosphere increases when these two parameters increase. As far as the spatial distribution of ozone is concerned, the highest concentrations are recorded at the periphery of the urban area and the lowest at the urban sites with heavy traffic, where ozone is destroyed by the NO emitted from traffic exhausts. This pattern is observed during all seasons of the year. A critical factor leading to increased ozone concentrations at the northern and the eastern side of the Athens basin, especially in spring and summer is the development of sea-breeze cells regulating the movements of air masses at the Saronicos Gulf. As a result, the north-eastern edges of the Athens basin are located downwind of the urban area and they receive the maximum of the local photochemical ozone production, which is initiated by the ozone precursor emissions of the urban area (NOx, hydrocarbons) in combination with the intense sunlight and high temperatures. Another important factor contributing to the high ozone levels at the periphery of the urban area of Athens are the high background ozone levels observed in the Mediterranean basin during spring and summer as reported in the literature during the recent years. Concentrations exceeding 120 g/m3 are frequently observed during summer afternoons at rural sites, exceeding the eight-hour EU standard for human health protection.

b) PM10
Concerning the seasonal variation amplitude of PM10 particle concentrations, it is observed that it is weaker than the corresponding one observed for ozone. In most places appearing on the map areas and for most of the time the concentrations are in the 40 - 50 g/m³ range. The 50 g/m³ daily average EU standard for human health protection is exceeded during all seasons of the year, mostly in spring and summer. The examination of the spatial distribution of PM10 particle concentrations in the Athens urban area shows that during the spring season the highest concentrations (>50 g/m³) are observed at the central and south locations of the Athens urban area but also at the northern and eastern peripheral sites. During the summer season, exceedances of the 50 g/m³ daily average EU standard are observed at the southern part of the Athens basin only. During fall and winter the extent of the areas with PM10 particle values higher than 50 g/m³ is much more restricted in comparison to the corresponding extent observed in spring and summer (mainly at the centre and the north of the urban area).

3) Epidemiological modelling and risks maps

In the four cities in the period 1 January 2003 to 31 December 2005 (in Rome to 31 December 2004) cardiovascular (ICD-9 codes 390-459 or ICD-10 codes I00-I99) and respiratory (ICD-9 codes 460-519 or ICD-10 codes J00-J99) events we collected using hospital discharge data.

The dependent variables were daily respiratory or cardiovascular morbidity and mortality among persons residing in the four cities across the study period.

Using a Poisson regression model, relative risks (RRs) were calculated for the studied pollutants:

- PM10 (24 hours mean values expressed as g/m³ and measured in actual conditions);
- O3 (daily maximum 8-hr mean values expressed as g/m³ and measured at 20 °C and 1013 hPa).

The RRs derived from the Poisson models were used in order to calculate the attributable fraction (AF). This was used to estimate the fraction of the health outcome which can be attributed to the exposure in a certain population.

Finally, the number of cases attributed to the population exposure (NE) was calculated multiplying the population size times the rate attributed to the exposure in the population (IE), that in turn is the product of the attributable fraction for the baseline frequency of the selected health outcome in the population.

Applying in a GIS environment the above mentioned equations, we obtain the attributable fraction (AF) spatially resolved at the same spatial resolution of the pollutant concentration and the population data. Then we derived the absolute number of health outcome (e.g. the number of deaths) due to the considered pollution exposure levels on a cell-by-cell basis.

Having these results spatially resolved, the GIS allowed for further processing of the data such as reckoning the sum of all the events at specific geographic reference units (e.g. the ZIP code), allowing the calculation of the total number of events (deaths or hospital admissions) aggregated for specific city zones or areas.
4) Identification of areas at high risk

HEREPLUS was able to produce risk maps of the estimated absolute number of cases (aggregated on municipalities) attributed to the exposure to the studied pollutants, utilizing the GIS approach.

5) Assessment of pollutant uptake and deposition to urban green and exposure reduction potential due to the vegetation sink capacity

The reduction of air pollution by urban green has been recognised as a cost effective component of air quality amelioration in several urban areas around the world. Robust evidence exists that plant physiology, abundance, and distribution within cities are basic parameters affecting the magnitude and efficiency of air pollution removal.

Within the HEREPLUS project, different integrated methodologies have been developed and applied for the assessment of the role of urban vegetation on the removal of two air pollutants, tropospheric ozone (O3) and PM10, in a spatially resolved form in the three urban areas of Rome, Madrid and Athens.

The approach implemented in the city of Rome, couples a system dynamic plant physiological model (MOCA-Flux, Manes et al., 1998; Vitale et al., 2003; 2005), previously validated in the survey area (Gerosa et al., 2005; Vitale et al., 2005), with GIS based high-resolution maps of the main vegetation types distribution, and climatic and pollution variables, derived by remote sensing and geo-statistical models applied to air quality monitoring data, respectively (Manes et al., 2008). Seasonal and annual ozone removal by three functional groups of urban trees (evergreen broadleaves, deciduous broadleaves and conifers) was estimated for years with fairly different climatic conditions. Different tree functional groups showed complementary uptake patterns, related to tree physiology, phenology and spatial distribution, maintaining a stable community function across different climatic conditions. These results suggest the importance of urban tree diversity for stabilizing emerging ecosystem services, such as O3 removal in urban environment, thus enhancing human health and well-being. (Manes et al., submitted).

For PM10 the total amount yearly removed by these three functional groups has been obtained by integrating the mean daily deposition flux over the annual series. As for ozone, climate played an important role affecting leaf biomass production and therefore LAI (Leaf Area Index) values and removal capacity of some groups, like deciduous broadleaves with respect the others.

The exposure reduction potential due to the sink capacity of urban green for O3 and PM10 has been also detailed quantified in the Villa Ada Urban Park. It is the largest green area at the very centre of the city (around 186 ha covered by woody vegetation), located within the borders of the Sanitary District RMA. Total cumulated O3 fluxes and PM10 depositions to woody vegetation where compared to simulated scenarios of total depositions in absence of vegetation, in order to estimate the mitigating role of urban green for both pollutants. Seasonal scenarios where considered for two cases: 'real' (actual vegetation cover for evergreen broadleaves, deciduous broadleaves and conifers), and 'no vegetation' (bare soil replacing woody vegetation at all locations). Total ozone fluxes and PM10 depositions to vegetation were calculated as described above, for all leaf types, while total depositions to bare soil were estimated by applying reference values of O3 and PM10 deposition velocity to bare soil, to the GIS-based maps of
estimated O3 concentration. For O3, a sequence of daily cumulated stomatal flux maps (g m⁻²) was produced for evergreen broadleaves, deciduous broadleaves and conifers, from which four seasonal scenarios for the 'real' case (actual vegetation cover), and 'no vegetation' (bare soil replacing woody vegetation at all locations), were derived.

The results show a conspicuous contribution of all the three vegetation leaf-types in removing pollutants from the urban atmosphere. The different leaf types have a different removal performance during the year: in particular, during the extremely dry year 2003, evergreen broadleaves played the most effective role, overcoming conifers and deciduous broadleaves in removing both O3 and PM10. These estimates represent a case-study to show the fundamental role of urban green areas in mitigating air pollution, with important implications also for public health.

The approach implemented in the city of Madrid, is based on the application of an air quality model (CHIMERE), whose parameterisation has been improved to specifically considering the ecophysiology of the Mediterranean vegetation. This model, validated for the study area, simulates the chemistry and transport of pollutants in the air (Alonso et al., 2011) using the pollutant emission inventory and actual land cover information of the area. The potential of urban vegetation for improving air quality in this region has been estimated by substituting a peri-urban broadleaf evergreen forest (El Pardo area, about 16000 Ha) by bare soil simulating a hypothetical case. This fact drastically reduced O3 deposition over the forested area, but increased both O3 deposition and air concentrations in the surroundings. The presence of the forest implies an hourly air quality improvement up to 14 % in O3 values, confirming the prevailing sink effect, even though the main species, identified as strong monoterpene emitter, represents a high O3 formation potential as biogenic precursor source.

An additional work was performed to test the efficiency of different vegetation types in ameliorating urban air quality modelling stomatal O3 fluxes absorbed by different types of vegetation. As for Rome, evergreen broadleaf and deciduous tree species removed more atmospheric O3 than conifer forests, and also substantial seasonal differences between leaf types were observed depending on plant phenology and physiology. Interestingly, O3 uptake fluxes during spring were higher in evergreen broadleaf than in deciduous forests, while the opposite situation was observed in summer.

The simulation exercise also demonstrated the sink effect of the forested area to ameliorate PM10 concentrations, also in the areas surrounding the forest albeit depending on meteorological conditions.

In the city of Athens, the contribution of two evergreen species in the absorption of gaseous pollutants, and in particular of O3, was estimated through stomatal conductance modelling. Results have shown a higher level of gas exchange of Quercus ilex (twofold) in respect to Pinus halepensis during the summer period.

The effects of these two evergreen species on the PM10 removal capacity, has been also quantified showing the higher amount removed by Quercus ilex, with respect to Pinus halepensis and similar values as in Rome in terms of PM10 values by unitary surface of vegetation cover.

The results obtained in these three cities have highlighted important conclusions on the sink capacity of urban vegetation on O3 and PM10 ambient concentrations. Variability found in this capacity has been
associated to climatic conditions, seasonality, atmospheric dynamics, and abundance, distribution and physiology of vegetation within cities. Limited water availability in summer reduces the stomatal conductance of plants, decreasing dry deposition over these surfaces. In addition, many species characteristics of Mediterranean vegetation emit high rates of BVOCs, thus the production of O3 and particles from BVOCs may represent a significant air quality challenge that needs to be addressed. Additionally, management practices can further enhance urban and peri-urban vegetation benefits through controlling canopy cover and tree crown dimensions to maximize air pollution removal.

In conclusion, HEREPLUS findings once extended to other urban environments, vegetation types, and climatic conditions, could bear important implications for environmental policy and green management plans oriented at increasing provision of ecosystem services in large metropolitan areas, while contributing to a comprehensive valuing of urban forest diversity.

6) Guidelines for urban environment management

The guidelines for establishing urban-environmental measures to minimise the health costs associated to urban ambient air pollution have been expressed in the form of best practice recommendations and proposals for urban management measures that may be used as a baseline for municipal administrations.

Best practice recommendations cover primarily two aspects:

a) improvement of air quality monitoring networks based on a better assessment of the spatial extent of urban air pollution and its impacts on public health; and
b) optimal use of urban green to enhance its pollution sinking capacity, respecting the local climatic and environmental conditions, including land use planning considerations.

The key message of the HEREPLUS work for all stakeholders concerned with managing the link between urban air pollution and public health in European cities can be summarised as follows:

- urban green spaces as a multifunctional system are significant for sustainable development, providing substantial ecosystems services for human well-being;
- a deeper knowledge on the role of different vegetation types is crucial to ameliorate detrimental environmental conditions (e.g. poor air quality) and health-related quality of life.

The main motivation for conserving urban biodiversity can be summarised as follows:

- to provide ecosystem services to improve human health and well-being in a global change context;
- to preserve important local biodiversity and ecological corridors;
- to provide environmental education.

There is the need for assessing abandoned urban sites, both built an non built, to be included in restoration planning aimed at increasing vegetation cover and maintaining local biodiversity structure and functions. There is the need to coordinate the activities among the environment, health and mobility decision-makers, to better transfer the scientific knowledge obtained by multidisciplinary studies related to
GIS analysis of green areas in urban environment, and in elaborating plans for improving the quality of citizens living in urban areas.

Furthermore, the project made an overview of possible measures that, if taken today in the four demonstration cities of the project, namely Madrid, Rome, Athens and Dresden, would result in significant improvement in urban air quality with the corresponding benefits on public health. Such measures, in addition to urban green space management, include actions that tackle sustainable mobility and change of transport modes in the cities, introduction of pedestrian and cycling zones / lanes, intelligent traffic and parking management, fiscal measures that promote sustainable transport, energy management in buildings, use of environmental and transport information systems, measures to enhance public awareness.

One of the critical points for conducting and improving spatial epidemiology and consequently for assessing the potential health benefit due to the vegetation is the determination of air pollution concentration fields at high spatial resolution. In the cities where the monitoring networks of which have been designed and adapted to the 2008/50 European Directive on ambient air quality and cleaner air for Europe, other methods can be applied for assessing the air quality while reducing the required number of ground monitors. According to this Directive, modelling techniques not only can be applied as a useful tool for assessment the air quality in a whole territory, but as it is stated, they 'should be applied where possible, to enable point data to be interpreted in terms of geographical distribution of pollutant concentrations. This could serve as a basis for calculating the collective exposure of the population living in the area'.

To estimate the pollution concentration at any specified point and time, modelling techniques should take into account all different processes involved. These include the emission sources, from where the primary pollutant is emitted directly to the atmosphere, up to the knowledge and parameterization of all the different physical and chemical mechanisms that drive to that a specific pollutant can be measured in the ambient air or be removed by other different mechanisms of deposition before being eliminated from the atmosphere.

Most of these air quality models encompass a high degree of complexity that sophisticates as more detail on physical mechanisms (transport diffusion, deposition) or chemical reactions are taken into account. This is particularly true in cases of secondary pollutants like ozone or secondary particulate matter. In these cases, these behave as secondary species, that are subject to a non lineal chemistry and whose precursor species are still not well documented. The emission inventory for these two pollutants, including anthropogenic and natural origin sources, is another piece of the puzzle that requires a high degree of information, spatially and time resolved, and is not easily available for all cities. Other important piece, also related to the inputs required by such type of air quality models is meteorology. Frequently, this part is obtained by meteorological models which provide the spatial fields of meteorological variables and other atmospheric parameters, and their time evolution, needed for their coupling with the air quality models. These meteorological models require detailed information or measurements in the work domain and boundary conditions.

Despite being based on a very extensive set of local information, and scientifically sound physical and
chemical fundamentals, or mainly due to these reasons, this tool can be very time consuming as large amount of information is needed to provide a concentration field for a specified day and pollutant, also requiring a great computing power. To overcome these limiting factors and improve the spatial resolution of the pollution concentration fields we propose a methodology which makes use of two distinct approaches which can also be integrated in a single common framework: the first one is based on the use of advanced geostatistical techniques and the second one makes use of satellite images suitably post-processed. These methodologies can be applied separately. However, their integration into a single common methodological framework through the application of data fusion techniques, which combine quantitatively the results obtained by the two cited methods to derive the final pollution concentration field with the lowest error is a net methodological improvement. Satellite measurements can complement surface level monitoring networks by identifying processes (e.g. long-range transport) through adding a more detailed spatial dimension. However, support from remote sensing to air quality assessment needs more regular high resolution satellite passes and data processing capacities to provide near real time output. The results obtained from satellite imagery can be seen as very high resolution (up to 10 m) snapshots of the actual pollution levels over a certain area in one precise moment and it has the unique advantage to embrace all the emission sources existing in the investigated area. This detailed information could be used to ‘calibrate’ the results from the other method through fine-tuning adjustment of the different parameters affecting the final result.

Potential impact:

The methodology developed in HEREPLUS has shown its potential as methodological framework for enhancing the quality of decision making processes for what concerns urban environmental and health measures. The project provided an overview of possible measures (e.g. urban green function analysis and management actions, improved methodologies for air pollution monitoring and health impact assessment) that, if taken today in the four demonstration cities of the project, would result in significant improvement in urban air quality with the corresponding benefits on public health. The HEREPLUS work has allowed deriving some key messages for all Stakeholders concerned with managing the link between urban air pollution and public health, especially through urban green management, in European cities. First of all, urban tree diversity has resulted to be a cost effective tool for stabilizing emerging ecosystem services, such as O3 and PM10 removal in urban environment, thus enhancing human health and well-being. This could bear important implications for environmental policy and green management plans oriented at increasing provision of ecosystem services in large metropolitan areas, while contributing to a comprehensive valuing of urban forest diversity. The project has also highlighted the need to step up cooperation and coordination between stakeholders in the environment, health and mobility fields, as well as between Stakeholders and researches. This will allow to better transfer the scientific knowledge obtained by multidisciplinary studies related to GIS analysis of green areas in urban environment, and in elaborating plans for improving the quality of citizens living in urban areas.

Another potential impact of the project lays in the transferability of its methodological approach to other urban areas. Transferability of the methodology and the potential for its implementation within any urban hotspot experiencing environment and health concerns has been evaluated, taking into account the following guidelines:
- ensuring that methodology can be applied by users with different skills and backgrounds;
- providing valid and suitable alternatives in case some information gaps could be identified in some specific local applications or in other words, the structure of the methodology proposed should be flexible, so that the system can be adapted to meet local specific and changing needs.

The bottleneck, which can occur when all the elements are transferred to a new site, is related to the definition of administrative tasks, since environmental management rules can be very different according to different laws / rules existing in EU and non-EU countries.

The integrated methodology developed within HEREPLUS is therefore able to contribute in collecting reliable information on the impact environmental damage has on human health in urban environments. In this sense, the HEREPLUS results represent a valuable contribution to the EU Environment and Health Action Plan, as well as to the Global Earth Observation System of Systems (GEOSS), aiming to monitor and forecast all environmental factors (including also pollutant distribution) affecting human health.

Finally, from a strictly scientific point of view, HEREPLUS has represented a test bench to the development of interdisciplinary studies involving physicians, ecologists, atmospheric chemists, statisticians, modellers and GIS experts, taking into account the complexity of urban systems in relation to air quality, human health, and green functions. This multidisciplinary consortium could therefore serve as a model for an integrated research network among EU scientists.

Dissemination activities

The dissemination activities carried out during the life of the project were the following:

1) Stakeholders panel

Since the inception of the project, HEREPLUS established a stakeholder panel, including representatives of local and national institutions responsible for urban air quality and public health management.

The stakeholder panel was intended to provide direct interaction and to support cooperation between end-users and researchers at different levels of project development, thus allowing the end-users to give input, suggestions and feedbacks to the project’s activities. Therefore, the stakeholder panel was an open forum for discussion and synchronization within the project consortium. In order to highlight the availability of results the stakeholder panel was provided with public access to selected deliverables including technical overviews. This has ensured that researchers and potential end-users will benefit from the activities of the consortium.

The panel met two times during the duration of the project:

- first stakeholders panel meeting held in Dresden (30 September - 1 October 2009);
- second stakeholders panel meeting held in Athens (7 October 2010).

The stakeholder panel was composed by:
- Municipality of Rome: the Department of Environmental and Urban Green Policies; the X Department is the responsible of all those processes concerning the recovery, the preservation and the enhancement of the environment; the reduction of all the pollution factors, the development of specific strategies for a sustainable mobility in the Municipality of Rome, the planning of activities related to urban waste management, the bio-agriculture, the welfare and protection of animals. Those macro-functions define the activities of the X Department aimed at the air and noise pollution control through data survey and consequently reduction-acts for pollutants emissions;

- Municipality of Madrid: the Municipality of Madrid and especially the Environment Department is in charge of waste and air pollution, water conservation, air quality and acoustic control, climate change and sustainable development;

- Hellenic Ministry of Environment: Greece applies an integrated policy for sustainable development. The ministry, as the main body for handling environmental policy, has launched a broad range project to deal with the problems that concern the quality of life. Thus, apart from the well-known and widely discussed problems, such as atmospheric and water pollution, noise problems and waste disposal management, issues such as physical and urban planning and cadastre, will also be addressed by implementing the necessary measures for integrated and sustainable development;

- Municipality of Dresden: The Health Office of the Municipality of Dresden is the stakeholder for HEREPLUS project. The health area is involved in the environmental issue, the health office is part of a cross-sectoral team for the revision of the clean air plan;

- Saxon State Agency for Environment: the Saxon State Ministry of Environment and Agriculture is focus especially on soil / contaminated industrial sites, geology, climate, air, noise, refuse, environmental alliances, nature, radiation protection, agriculture marketing.

2) Workshop / conference organization

During the project, the following four local workshops took place:

1) Rome - 18 February 2011 attended by about 15 persons;
2) Dresden - 31 March 2011 attended by about 8 persons;
3) Athens - 1 April 2011 attended by about 10 persons;
4) Madrid - 4 May 2011 attended by about 20 persons.

All the workshops were devoted to present and discuss with local stakeholders the results obtained by HEREPLUS as well as the possible developments of the relationship established during the project duration for further information, please see deliverable D1.3 'Report from the second stakeholders panel meeting'.

Moreover, as the final event of the project, it was organized the International workshop 'Reducing air pollution and health risk through urban green diversity', held in Rome on 31 May 2011, which was attended by about 50 persons. The first part of the workshop was devoted to the presentation of the project structure and achievements, while the second part was devoted to the interactions that HEREPLUS established with project stakeholders. In particular, representatives of the Municipality of Rome, the Municipality of Madrid, the Hellenic Ministry of Environment (the relevant presentation was
made by Dr Kalabokas from the Academy of Athens) and the Saxon State Agency for Environment illustrated the relevant policies, the collaboration with HEREPLUS, as well as the possibility of implementing the operational manual developed within the project.

3) Publications

During the project duration, partners have published 5 articles in journals while 14 articles were published in proceedings of international symposia. Moreover, two papers have been already accepted for publications, while two paper have been already submitted.

4) Presentations

In order to promote the project the partners have also attended sector related events. The attendance to these events gave to the partners the possibility to meet stakeholders and the scientific community and to raise awareness both on the project objectives and results. A total of 14 presentations were made, while 3 presentations have been already accepted.

Project website:

The HEREPLUS website project has been implemented around the idea of playing a twofold role:

- represent a 'window' of the project (i.e. containing useful and interesting information to the whole research community and other stakeholders);
- be an open forum for internal discussion and synchronisation within the project consortium.

In order to highlight the availability of results, the website has been built both to provide public access to selected deliverables (PU) and to contain a private session where partners and restricted groups could have a privileged access. This ensured researchers and potential partners to benefit from the activities of the consortium.

An FTP area has been created and is available for partners use, to exchange data, documents and other kind of information. This area allows partners to upload and download very complex documents, such as maps.

The website also contains a description of the project, information on participants, publications and ongoing activities. To encourage cooperation with other European projects, the web site also provides information and links to projects and activities correlated.

The website design has been implemented with the idea of finding an appealing graphical interface to instantly represent the challenge that the project wanted to meet: detecting and analysing health risk of environmental pollution levels in urban systems.

A polluted city has therefore been chosen for the background of the banner together with some environmental pollutants that from the urban system are originated. The proposed solution is suggested in
a window containing a green area to balance and contrast the environmental problem and which is presented together with the logo of the project and the description of its acronym. A reference to the Seventh Framework Programme (FP7) has also been represented within the banner.

Access to the partners involved in the project is also graphically encouraged by the help of a map of Europe presented in the home page where the cities / areas object of study within the project are highlighted and linked to the correspondent partner involved.

Related documents

Final Report - HEREPLUS (HEalth Risk from Environmental Pollution Levels in Urban Systems)

Last update: 18 January 2013

Permalink: https://cordis.europa.eu/project/id/212854/reporting

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