FINAL REPORT

DELIVERABLE D4.1:

Training material for secondary school teacher´s

Coordinated by:

idæa

12/2016

LIFE11 /ENV/ES/584

AIRUSE

Testing and development of air quality mitigation measures in Southern Europe

Contents

1 PREAMBLE

This document provides the material to be presented to secondary school teachers seminars organized by AIRUSE project. The aim of these seminars is to present the objectives and outcomes of the project and and also to raise public awareness on air quality issues. The seminar will contain a short description of the project´s actions and information on airborne particulate matter: definition, chemical composition, emission sources, health effects and effects on the environment, and also the current air quality standards.

2 PROJECT DESCRIPTION

AIRUSE is an international project which started on October 2012 and will be completed in September 2016. The project is co-funded by the European Commission, in the framework of LIFE+ Environment Policy and Governance programme.

Coordinating beneficiary for AIRUSE project is the **Spanish Council for Scientific Research.**

Other project beneficiaries are:

1. **N.C.S.R. "Demokritos"** (Greece)
2. **University of Aveiro** (Portugal)
3. **University of Florence** (Italy)
4. **Ceramic Industry Research Association** (Spain)
5. **University of Birmingham** (U.K.).

The main objective of the project is to provide to the National Authorities of Southern European countries the appropriate measures to reduce airborne particulate matter ($PM_{2.5}$ and PM_{10}) concentrations in air. In Southern Europe a great deal of improvement with respect to mitigation strategies can be made. The combination of diverse emission sources (dust intrusions) with the complex climatology (strong radiation, high photochemical conversion rates, low rainfall rate) significantly enhance the particle levels in South European and Mediterranean countries.

In this framework, AIRUSE project has the following objectives:

- Determine the source contribution of the emission sources and identify those that are responsible for the PM limit values exceedances.
- Quantitatively evaluate the effect of air quality mitigation measures already used and will be used by national authorities.
- Develop and propose effective air mitigation measures for South European countries.
- Allow the adaptation of control strategies capable of reducing exposure levels in South European countries.
- Assist National and Regional authorities to implement the "Thematic strategy on Air Pollution" and to formulate air quality action plans in the framework of Directive 2008/50/EC.
- Support effective policy making by the use of a communication strategy plan.
- Act as a catalyst for the allocation of local, national funds to the implementation of air mitigation strategies.

These objectives will be achieved through the following actions:

A. Preparatory actions

A.1 Authorities and stakeholders consultation

Prepare the technical part of the project by consulting local and national authorities for the mitigation measures already being used and the application of future measures.

B. Implementation actions

B.1 Documentation of the current status

Conduct an extensive review of the current status of the methods used for source identification and quantification of their contribution to airborne particulate matter (PM) levels (sources apportionment). The aim is to identify needs for harmonization, existing gaps and limitations in relation to policy purposes.

B.2 Harmonization of source apportionment and prioritization of pollution sources

Optimize and harmonize source apportionment methods in order to accurately resolve emission sources in the complex terrain of Southern Europe. Identification of the sources responsible for the exceedances of EU limit values.

B.3 Determination of the impact of natural sources (African dust, marine aerosol)

Determine the contribution of the natural sources, such as African dust and marine aerosol.

B.4 Determination of the impact of biomass burning

Determine the contribution of biomass combustion sources in the distinct scenario of Southern Europe.

B.5 Determination of the impact of industrial sources

Determine the contribution of industrial activities in PM_{10} and $PM_{2.5}$ levels.

B.6 Determination of the impact of traffic related sources

Determine the contribution of traffic related sources such as vehicles emissions and resuspended dust.

B.7 Testing of air mitigation measures – Development of air mitigation strategies

Test methodologies and practices, which reduce air pollution and exposure of the population.

B.8 Applicability of selected measures from Northern to Southern Europe

Compare mitigation measures used in Southern Europe with those of Northern Europe and adopt those measures that are considered appropriate to ensure better air quality in urban areas.

C. Monitoring of the actions impact

C.1 Effectiveness of the project actions

Measure the effectiveness of the project implementation actions as compared to the initial situation and the objectives and expected results. For the sound monitoring of the project's activities specific indicators will be set by the management team.

C.2 Assessment of the socio-economic impact of the project

Assess the economic cost of the proposed mitigation measures and also the benefits (health benefits, raised profile of the region, economic growth of the population) due to the improved air quality.

D. Communication and dissemination

D1 Project website

A project website will be designed as a tool to raise the profile of AIRUSE project and improve the dissemination of its activities to a wide range of stakeholders.

D.2 LIFE+ Information boards

The beneficiaries maintain notice boards describing the project at the locations where it is implemented, at strategic places accessible and visible to the public.

D.3 Networking-Open forum with key stake holders

Create an open forum with key stakeholders from industry, local and national authority policy makers where the complex output of the project will be translated into information which is targeted to policy makers.

D.4 Dissemination of project results

Publicize the outcomes of the project through the project’s website, newsletters, media (radio and television) and press releases, publications in workshops and conferences, production of technical guides, brochures and technical articles in scientific journals. Engage European Institutions to inform policy making at the highest levels. Organize seminars to local schools and to the general public in order to aware the citizens and convince them to adapt to the mitigation measures.

D.5 Production of Layman’s Report

Towards the end of the project, a Layman’s Report will be produced targeted at the general public and political decision-makers, outlining the main results of the project.

E. Project management

E.1 Project Management and Audit

Establish a management team composed of representatives of all partners and ensure availability of adequate resources on their behalf for the submission of correct financial (audit) and administrative data (reports). The project manager will have the general responsibility for the organization, planning and control of the project. The project manager will be responsible for the operation of the Open-forum with the policy makers, group of scientists, and representatives of the national authorities.

E.2 Monitoring of the project progress

The management team will define the indicators to be used to measure the progress of the project.

E.3 Networking with other projects

The project will provide a platform for networking of other LIFE projects that focus on the improvement of air quality (ACEPT-AIR, CMA, Med-P, PM3).

E.4 After-LIFE+ Communication Plan

An “After-LIFE Communication Plan” will include a road map of the long term application for the proposed mitigation measures and establish long term links between the stakeholders.

The main expected results from the project are:

- Comprehensive databases with the contribution of air pollution sources in the region of Southern Europe.
- Identification of the PM_{10} and $PM_{2.5}$ emission sources that are responsible for air quality standards exceedances.
- Development and demonstration of effective mitigation strategies for the most important PM sources in the region of Southern Europe.
- Reduction of PM_{10} and $PM_{2.5}$ levels towards the limits set in the EU Air Quality Directive (2008/50/EC), by means of practical and cost-effective strategies.

3 AIRBORNE PARTICULATE MATTER

3.1 Introduction

Airborne particulate matter (PM) or airborne particles include the solid or liquid particles suspended in the air. Their size varies from that of simple molecules ($\sim 2 \cdot 10^{-4}$ μm diameter) to diameters of around 100 μm. Airborne particles originate from a number of sources and thus present a wide range of morphological, chemical and physical properties. The atmospheric mass concentration of PM may vary from a few μg/m^3 to several hundreds of μg/m^3 in heavily polluted areas (Seinfeld & Pandis, 2006).

3.2 Particles classification based on size

Airborne particles present a number of different shapes; thus the selection of a common parameter for the definition of size is not possible. For that reason, size distributions are based on the “equivalent diameter” of particles. There are several definitions of this metric. The particles equivalent diameter may be defined:

- Geometrically (though optical or electron microscopy)
- Through light scattering
- By specific particles characteristics, such as their electrical mobility, deposition velocity or aerodynamic behavior.

The most commonly used equivalent diameter is the aerodynamic diameter, which depends on the particle density and is defined as “the diameter of a sphere with unit density that has aerodynamic behavior identical to that of the particle in question”.

The whole of airborne particles in the atmosphere are called Total Suspended Particles (TSP). The size distribution of particles reflects their sources and their chemical composition. Total suspended particles are classified into the following size groups (Figure 1):

1. Fine particles, with aerodynamic diameter up to 2.5 μm
   1.1. Nuclei mode / nuclei range or else ultrafine particles, with diameters from 0.01 to 0.1 μm.

These particles are emitted by combustion sources or are formed through condensation of combustion products. They present short atmospheric life times since they tend to coagulate between them or with other slightly larger particles.

1.2. Accumulation mode, with diameters from 0.1 to 2.5 μm.

These particles are formed through the coagulation of smaller particles and condensation of additional material. Accumulation mode particles are further classified into:

- Condensation mode
- Droplet mode

2. Coarse particles, with aerodynamic diameter larger than 2.5 μm

These particles are usually formed mechanically.

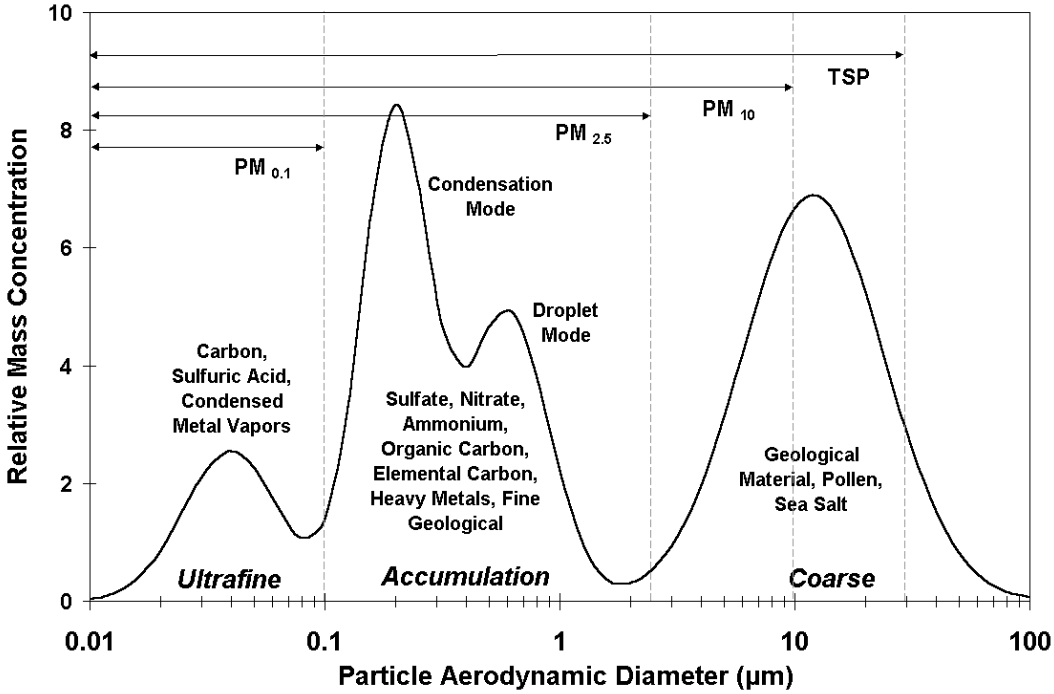

Figure 1. Typical size distribution of atmospheric particles.

3.3 Particles classification based on penetration to human organism

Particles' behavior into the human organism (respiratory system, stomach) has been and remains a subject of increased interest for the scientific community. According to the available data, particles are classified into the following categories, based on their ability to enter the human organism (Figure 2):

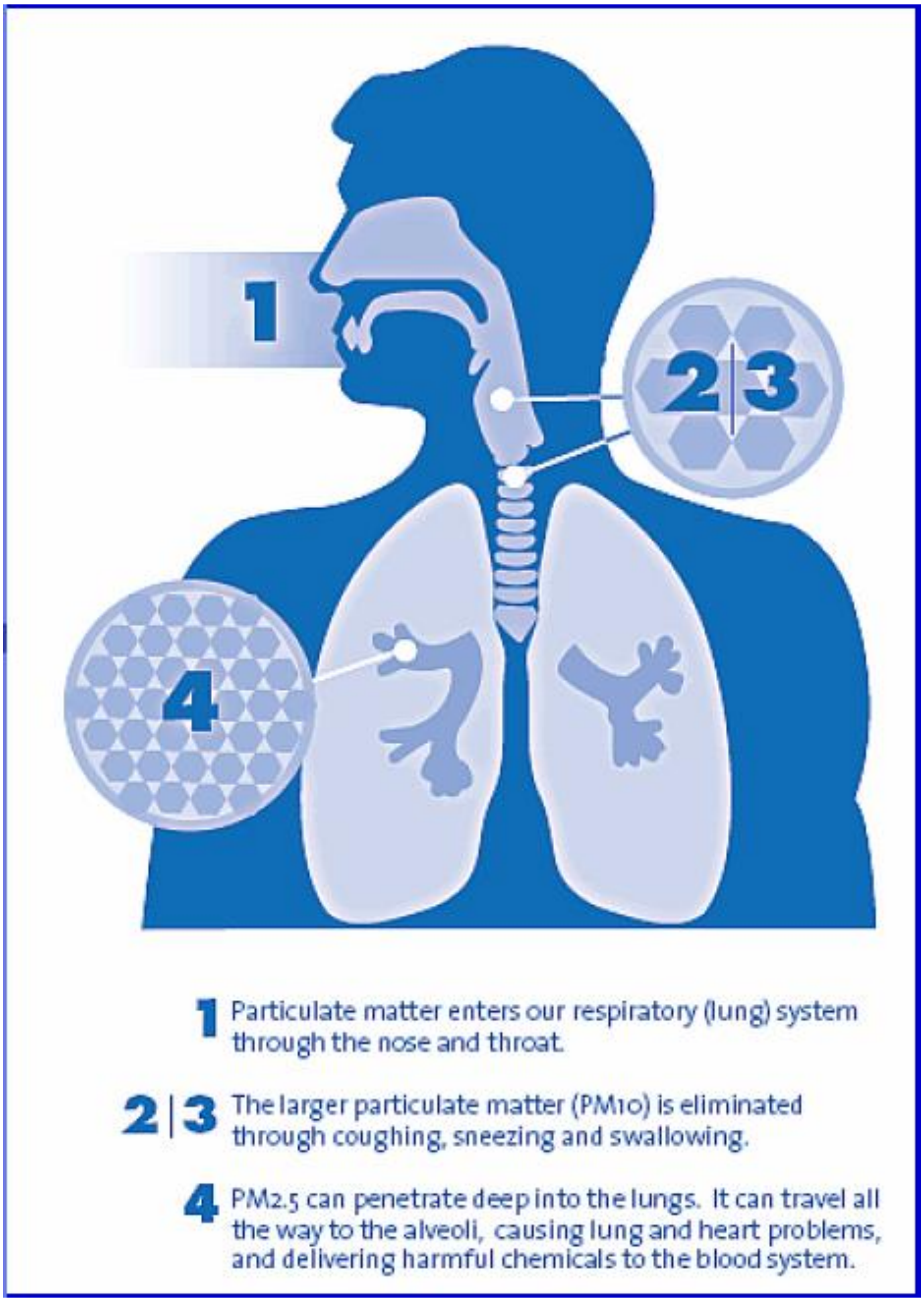

Figure 2. Airborne particles' penetration into the human organism.

1. Inhalable particles

Inhalable particles are these particles that enter the upper respiratory system (nasopharynx). They include particles with diameters less than 10 μm, since larger particles tend to deposit on the oral and nasal cavities.

2. Thoracic particles

Thoracic particles are the fraction of inhalable particles that penetrate the upper respiratory system. It is considered that they have diameters less than 7 μm.

3. Respirable particles

Particles with aerodynamic diameter less than 2.5 μm are the most health relevant fraction. These particles may penetrate deep into the lungs, traveling all the way to the alveoli.

3.4 Definition of measured particulate fractions

Based on the size classification of TSP (fine and coarse particles) and their ability to penetrate into the human organism (inhalable and respirable particles), two basic size fractions have been defined: PM_{10} and $PM_{2.5}$. These particle fractions are included in the criteria pollutants for air quality. Limit values for the ambient atmosphere have been set both in Europe and the U.S.A.

PM_{10} are generally considered to correspond to inhalable particles, having diameters less than 10 μm. Nevertheless samplers cannot function stepwise, collecting or excluding particles of a specific diameter. In reality PM_{10} include as well a limited number of particles with diameters larger than 10 μm. The exact definition of PM_{10}, as included in the E.C. Directives, is:

“PM_{10} are the particles which pass through a size-selective inlet with a 50% efficiency cut-off at 10 μm aerodynamic diameter.”

Similarly, $PM_{2.5}$ correspond to respirable particles and are defined as:

“$PM_{2.5}$ are the particles which pass through a size-selective inlet with a 50% efficiency cut-off at 2.5 μm aerodynamic diameter.”

During the last decades research activity has also focused in the study of another size fraction, that of ultrafine particles (UFPs). UFPs are particles with diameters below 0.1 μm. This size fraction contributes very little to the total mass concentration (due to their small size) but it dominates the number concentration (Woo et al., 2001). It has been documented that in big urban centers, where vehicular traffic is the main particle source, UFPs may account for more than 90% of the total particles in the atmosphere (Gramotnev & Ristovski, 2004; Morawska et al., 2004).

4 CHEMICAL COMPOSITION OF AIRBORNE PARTICLES

Particles chemical composition varies depending on their origin. The main chemical constituents may be classified as follows:

- Crustal constituents (Si, Al, Ca, Mg, etc.)
- Ionic constituents (Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, etc.)
- Trace elements (Pb, Cd, Cr, V, Zn, As, etc.)
- Carbonaceous matter (elemental carbon and organic compounds)

Size distribution of particle constituents varies and usually reflects their anthropogenic or natural sources. Crustal constituents are generally found in particles with diameters larger than 2.5 μm. Ionic constituents may be either primary (such as NaCl, KCl, $MgCl_2$) or secondary (such as $(NH_4)_2SO_4$, NH_4HSO_4, NH_4Cl, NH_4NO_3) formed through the reaction of gas precursors SO_2, NOx and HCl with NH_3. Anthropogenic ionic constituents are found in particles with diameters below 1 μm, while ionic components of natural origin are associated with larger particles.

Trace elements may originate from natural (soil resuspension) or anthropogenic sources (combustion of liquid or solid fuels, industrial emissions). Heavy metals (such as Pb, Cd, Cu, Zn, Ni, etc.) and volatile trace elements (As, Se, Sb, Br) are usually found in fine particles, while elements or crustal origin (Fe, Mn, Cr, etc.) are found in coarse particles.

Elemental carbon is emitted through incomplete combustion. Organic carbon may be of primary origin, such as alkanes, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) etc. It may be also of secondary formation through the condensation of gaseous hydrocarbons emitted by vehicles.

5 PARTICLE EMISSION SOURCES

Airborne particles are either primary (emitted directly into the atmosphere) or secondary (formed in the atmosphere from gaseous precursors through homogeneous or heterogeneous reactions)

The main primary sources are:

Vehicular traffic: The main sources of airborne particles are vehicles' exhaust and tyre and break wear. Vehicular traffic also causes road dust resuspension.

Industrial activities: Industrial emission may contribute to urban PM concentrations depending on the proximity of industries to urban areas and the technology applied. Airborne particles emitted by the different industrial processes present varied characteristics. Their size is in the range 0.5 – 100 μm. Among the industries emitting significant amounts of particles are: energy production, chemical, agricultural and food, metallurgical, inorganic and mineral production and chemical paper mass production industries, as well as oil refineries (Querol et al., 2000).

Waste incineration: Incineration is a widely used method of waste disposal in many European countries. The emitted particles are mainly composed of unburnt inorganic matter, with typical size between 1 to 50 μm in diameter. Waste incineration may also emit heavy metals (such as As, Cd, Ni, Pb, Zn and Hg), in the form of their oxides and chlorides. These compounds are produced due to the presence in the waste of material such as batteries, plastics and metal alloys.

Residential sources: The main source of airborne particles is residences' central heating. Lately the use of biomass for residential heating has increased in developed countries, resulting in significant concentration levels during winter season.

Forest and agricultural fires: Both direct emissions of particles and the reuspension of soil dust from the incinerated land may be significant sources of airborne particles. These particles are composed of organic matter, elemental carbon and inorganic constituents.

Particle long-range transport: It has been assessed that 150 million tons of dust are transported each year from the Sahara desert to the North hemisphere. The intensity of this phenomenon is decreased with increasing soil humidity and vegetation coverage. The transported dust particles are generally coarse particles. They present high content of calcite and smaller amounts of gypsum, clay materials and metals.

Long range transport of particles may be related to other emission sources as well, such as wildfires or agricultural fires and industrial/urban pollution leading to the formation of secondary pollutants in neighboring or more remote locations.

Soil dust resuspension: Dust resuspension from the soil is affected by meteorological mechanisms, such as wind and changes in temperature and humidity. Size distribution of particles depends on the type of the original particle source. Their size is in the range 5 – 50 μm. Their chemical composition is similar to that of geological material (dolomite, gypsum, quartz and claystone).

Sea aerosol: The breaking of sea waves produces small droplets of sea water which dry out through evaporation and produce airborne particles of sea salt. Particles are also emitted through the breaking of air bubbles on the sea surface. Sea salt particles’ size ranges from 1 to 20 μm.

Volcanic activity: Fly ash emitted by volcanoes may be a significant source of airborne particles for the neighboring areas.

Secondary particles are formed from gaseous precursors emitted mainly by vehicular traffic, industrial activities, as well as natural sources. For example, sulfur dioxide is formed from the oxidation of dimethyl sulfide which is produced by the sea phytoplankton, while it is also emitted by volcanoes. Secondary particles may be formed in the atmosphere in the course of some hours or days.

6 PARTICULATE POLLUTION EFFECTS

6.1 Human health

Several epidemiological studies have demonstrated a relationship between exposure to airborne particles and significant effects on human health (Samoli et al., 2005). Particulate air pollution has been found to cause or aggravate respiratory and cardiovascular diseases, to interfere with the self-cleaning mechanism of the human body and to damage the lung tissues, while it has been also associated with increased cancer incidence and premature death.

Toxicological studies are still not able to provide the exact mechanisms behind the above mentioned adverse health effects. Nevertheless it has been estimated that long-term exposure to high PM concentrations may decrease life expectancy by 1-2 years on average. According to the World Health Organization (WHO), exposure to airborne particles results in approximately 3,000,000 deaths per year on a global level. It has been also demonstrated that particles present adverse health effects even at concentrations much lower than the limit values set by air quality standards. In its annual report, WHO mentions that according to the available data on long-term and short-term population exposure to airborne particles, no limit values may be set below which there are no health effects from PM exposure (WHO, 2006).

The most sensitive population subgroups are young and elderly people, as well as people suffering from cardiovascular and respiratory diseases. The group of pre-adolescent children has been extensively studied, regarding the micro-environments of peak exposures and the relevant health effects.

6.2 Natural and built environment

Airborne particles may alter our perception of the color of objects as well as of the atmosphere itself. The interaction of fine particles with solar radiation results in a reduction of visibility. Particles may absorb or reflect the solar radiation, thus leading to decreased visibility. It has been observed than PM concentration of around 150 $\mu g/m^3$ leads to maximum visibility of 8 km. In addition, due to the decreased solar radiation, agricultural production is also reduced.

Airborne particles may significantly affect the climate as well. Their effects vary and are strongly dependent on the local emission sources, particles' atmospheric lifetime and their interaction with solar radiation. Depending on their size and chemical composition, airborne particles may scatter or absorb the incoming short wavelength ultraviolet radiation or the outgoing long wavelength infrared radiation. The corresponding effects are cooling of the atmosphere in the first case and warming in the second case, (greenhouse effect). Airborne particles may also affect the climate indirectly, by altering the microphysical properties of clouds. The most significant consequence of particles interaction with clouds is the decrease of the size of cloud droplets. Particles act as condensation nuclei, triggering the formation of new droplets and thus depriving clouds from the largest droplets. Other effects of particulate air pollution are the increase of clouds lifetime and the chemical pollution of rain droplets (acid rain).

Airborne particles may also cause significant deterioration of the built environment. The main mechanisms involved are corrosion and deposition of particulate matter, resulting in chemical damage and/or soiling of the surfaces of the indoor and outdoor environment.

7 AIR QUALITY STANDARDS

The documented detrimental effects of airborne particles in human health as well as the environment have lead to the development of international and national mitigation policies, through the establishment of limit values for PM concentrations and emissions and the implementation of control measures. Member-states of the E.C. follow the E.C. Directive 2008/50/EC of the European Parliament and of the Council "on ambient air quality and cleaner air for Europe". Directive 2008/50/EC sets limit values for particles with aerodynamic diameters less than 10 μm (PM_{10}) and less than 2.5 μm ($PM_{2.5}$) (Table 1). It also provides methodologies for the measurement of these particle fractions and criteria for the assessment of air quality.

Table 1. Limit values for PM concentrations in ambient atmosphere, according to Directive 2008/50/EC.

	Reference period	Limit value
PM_{10}		
24-hr standard	24 hours	50 μg/m^3 (not to be exceeded more than 35 days per year)
Yearly standard	1 calendar year	40 μg/m^3
$PM_{2.5}$		
Target value	1 calendar year	25 μg/m^3

8 REFERENCES

1. Gramotnev G., Ristovski Z., "Experimental Investigation of Ultrafine Particle Size Distribution near a Busy Road", Atmospheric Environment, Vol. 38(12), pp. 1767-1776, 2004.
2. Morawska L., Thomas S., Hofmann W., Ristovski Z., Jamriska M., Rettenmoser T., Kagerer S., "Exploratory Cross-Sectional Investigations on Ambient Submicrometer Particles in Salzburg, Austria", Atmospheric Environment, Vol. 38(21), pp. 3529-3533, 2004.
3. Querol X., Alastuey A., Lopez-Soler A., Plana F., "Levels and Chemistry of Atmospheric Particulates induced by a Spill of Heavy Metal Mining Wastes in Donana Area, Southwest Spain", Atmospheric Environment, Vol. 34, pp. 239-253, 2000.
4. Samoli E., Analitis A., Touloumi G., Schwartz J., Anderson H.R., Sunyer J., Bisanti L., Zmirou D., Vonk J.M., Pekkanen J., Goodman P., Paldy A., Schindler C., Katsouyanni K., "Estimating the Exposure–Response Relationships between Particulate Matter and Mortality within the APHEA Multicity Project", Environmental Health Perspectives, Vol. 113(1), pp. 88–95, 2005.
5. Seinfeld J.H., Pandis S.N., "Atmospheric Chemistry and Physics – From Air Pollution to Climate Change", 2nd Edition, John Wiley & Sons, Inc., New Jersey, 2006.
6. WHO, "WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide", World Health Organization Press, Switzerland, 2006.
7. Woo K.S., Chen D.R., Pui D.Y.H., McMurry P.H., "Measurement of Atlanta Aerosol Size Distribution: Observations of Ultrafine Particle Events", Aerosol Science and Technology, Vol. 34(1), pp. 75-87, 2001.

LIFE11 /ENV/ES/584

AIRUSE

Testing and development of air quality mitigation measures in Southern Europe

Final Report coordination team:

Project Manager: **Xavier Querol**
xavier.querol@idaea.csic.es

Scientific Manager: **Angeliki Karanasiou**
angeliki.karanasiou@idaea.csic.es

Administrative and Financial Management: **Cristina de Vasconcelos**
cristina.vasconcelos@idaea.csic.es

CSIC

idæa