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ICARUS Policy Brief - First issue

Integrated Climate forcing and Air pollution Reduction in Urban Systems

The ICARUS project

ICARUS is a Horizon 2020 project, whose main objective is to develop integrated tools and strategies for urban impact assessment in support of air quality and climate change governance in EU Member States leading to the design and implementation of appropriate abatement strategies to improve the air quality and reduce the carbon footprint in European cities. The project will develop detailed policies and measures for air pollution and climate control for the short and medium term (until ca. 2030). For the long term perspective (2050 and beyond) ICARUS will develop visions of green cities and explore pathways on how to start realizing these visions.

On board are experts of 19 Partner Institutions from 10 European countries, all with multidisciplinary expertise and experience in intersecting and complimentary research in research areas related to the climate and the environment and their interactions with health and wellbeing. The high scientific quality of the ICARUS team is based on the extensive and long-term experience of the partners, which include leading scientists and risk health research institutes in Europe.

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KEY FACTS

Air Pollution?

Ground-level ozone (O_3) is a gas formed by a number of chemical reactions between other air pollutants e.g. the man-made nitrogen oxides emitted from traffic and volatile organic compounds (VOCs).

Particulate matter smaller than 2.5 µm ($PM_{2.5}$) is solid or liquid particles emitted directly to the atmosphere or secondary particles formed chemically within the atmosphere. The sources can be both natural (e.g. sea salt and dust particles) or anthropogenic (e.g. soot particles from combustion processes).

Both ozone and $PM_{2.5}$ are associated with negative health impacts for humans. Particulate matter is e.g. known to be responsible for increased mortality linked to cardiovascular and respiratory diseases

- Polluted air was responsible in 2015 for 6.4 million deaths worldwide: 2.8 million from household air pollution and 4.2 million from ambient air pollution[1,2]. To get an idea of these numbers, in the same year, tobacco caused 7 million deaths, AIDS 1.2 million, tuberculosis 1.1 million, and malaria 0.7 million[3].
- Air pollution was responsible in 2015 for 19% of all cardiovascular deaths worldwide, 24% of ischaemic heart disease deaths, 21% of stroke deaths, and 23% of lung cancer deaths[3]. Additionally, ambient air pollution appears to be an important although not yet quantified risk factor for neurodevelopmental disorders in children5 and neurodegenerative diseases in adults[4]
- In the absence of affective and timely measures, ambient air pollution is estimated to cause to cause between 6 million and 9 million deaths per year in 2060[5].
- Ambient air pollution is responsible for great economic losses. These losses include medical expenditures—an estimated US$21 billion globally in 2015[5]—lost economic productivity resulting from pollution-related disease and premature death, and the cost of environmental degradation
- Air pollution and climate change are closely linked and may share common solutions (*win-win* solutions).
- Major emitters of carbon dioxide are coal-fired power plants, chemical producers, mining operations, and vehicles.
- Accelerating the switch to cleaner sources of energy will reduce air pollution and improve human and planetary health

[1] Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 2016; **388:** 1659–724.

[2] Prüss-Üstun A, Wolf J, Corvalán C, Bos R, Neira M. Preventing disease through healthy environments. A global assessment of the burden of disease from environmental risks. Geneva: World Health Organization, 2016

[3] Global, regional, and national life expectancy, all-cause mortality, and cause specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016; 388: 1459–544

[4] Grandjean P, Landrigan PJ. Neurobehavioural effects of developmental toxicity. Lancet Neurol 2014; 13: 330–38.

[5] Organisation for Economic Co-operation and Development. The economic consequences of outdoor air pollution. Paris: Organisation for Economic Co-operation and Development Publishing, 2016

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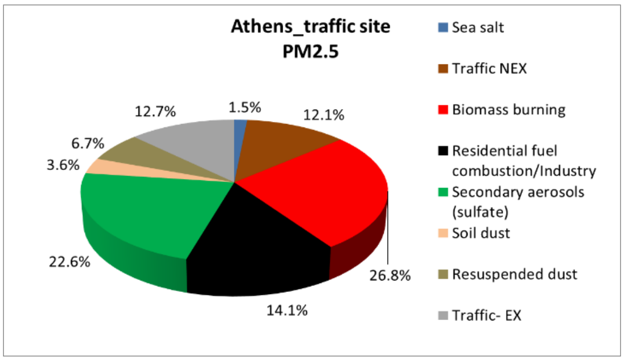
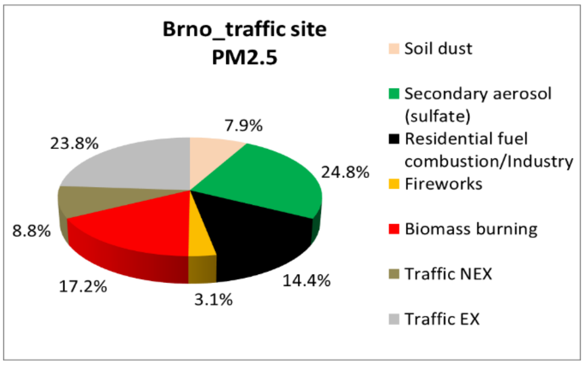
EMISSION SOURCES

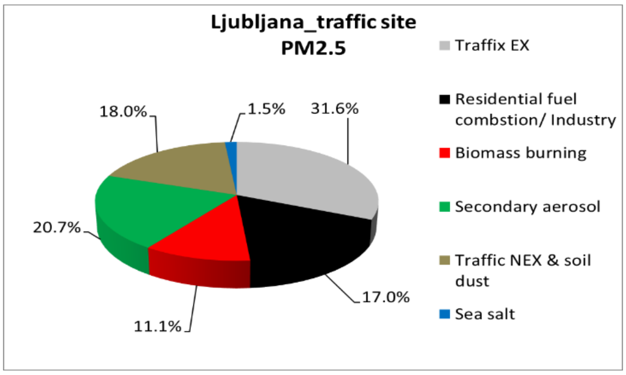
An extensive field campaign to measure $PM_{2.5}$ concentration took place in six European cities (Athens, Thessaloniki, Madrid, Stuttgart, Ljubljana, Brno) at three sites (urban background, traffic and regional) for one month during both the winter and summer seasons.

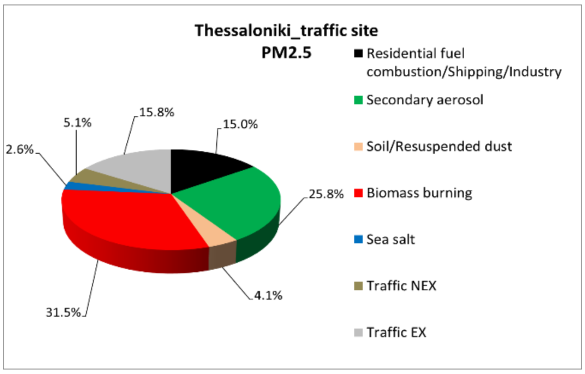
$PM_{2.5}$ samples collected during the ICARUS measurement campaigns were analyzed for 27 PAHs, 24 **trace elements** (Mg, Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ge, Br, Rb, Sr, Sb, Cs, Ba, Ce, Pb), **anions** (Cl^-, NO_3^-, SO_4^{2-}), **cations** (Mg^{2+}, Na^+, NH_4^+**), elemental and organic carbon** (EC, OC).

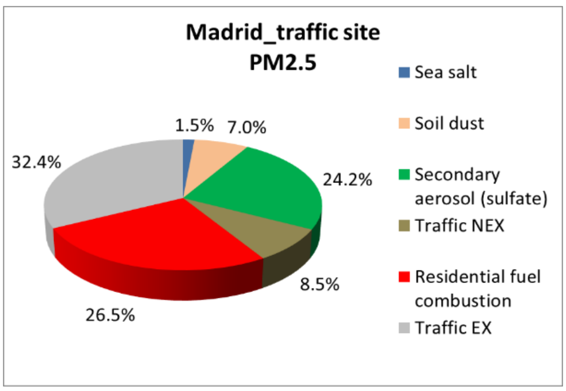
Chemical composition data were used in the **PMF** (Positive Matrix Factorization), **PCA** (Principal Component Analysis) and **Lenschow approach** models with the scope of identifying the main groups of sources and estimating their contribution to $PM_{2.5}$ concentrations. Indicatively, figures 1a-e show the % contribution of the emission sources to the measured $PM_{2.5}$ concentration for the traffic sites of Athens, Brno, Ljubljana, Madrid and Thessaloniki traffic sites.











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KEY RESULTS

PMF, PCA *approaches* resulted in identifying **three to eight** $PM_{2.5}$ sources/group of sources for each site/city:

- ***Biomass combustion*** contribution to $PM_{2.5}$ indicates the prevalence of the source during winter/fireplace-burning periods, without excluding biomass combustion emissions from agricultural activities (e.g. in the cases of Athens, Ljubljana and Thessaloniki rural sites). A significant variation of biomass burning contribution is noticed because of the strong dependence on the type of fuel and combustion devices used in each region for residential heating. The contribution varied from 11% (Ljubljana traffic site) to 40-43% (Thessaloniki, urban background and rural sites). The maximum contribution of biomass burning is observed at the urban background sites, because wood burning for heating occurs more often.
- **Fuel oil combustion** is associated with either residential heating or industrial emissions or shipping emissions (Thessaloniki port city) or combination of them. Its contribution varies between 8% and 27%.
- **Traffic i**s represented by two different factors: Traffic exhausts and non-exhaust emissions related to traffic. The contribution of traffic-related exhaust emissions ranged between 6% (Thessaloniki rural) and 32% (Ljubljana traffic site). In all cases, this source contribution was higher at the traffic sites of the cities. Non-exhaust emissions related to traffic, including anthropogenic dust sources such as elemental materials emitted from vehicles brake pads, tires and mechanical parts, presents different profiles among the several sites in Europe; its contribution ranged between 3% (Athens rural site) and 25% (Ljubljana urban background site, including soil dust).
- **Secondary aerosol** was identified either as secondary sulfate only, or as secondary sulfates and nitrate. This secondary aerosol factor may represent not only the formation of secondary aerosol over relatively long distances, but also a part of traffic-related pollution. Consequently, the contribution of this source varies substantially among the different sites considered: from 9% to 34%.
- Two natural-origin sources were identified: soil dust and sea salt. **Soil dust** associated with elements from the earth's crust presented different profile among the sites, even in the same city while its contribution ranged between 4% and 27%. The contribution of **sea salt** obtained its minimum values (1-4%) in Athens, Ljubljana and Thessaloniki. Chloride to sodium ratio values (<1.8) at the source profile indicated its aged form, as expected due to long distances from the coast.

Some more insights are obtained from the application of the ***Lenschow approach***:

- Around 40 % of $PM_{2.5}$ emissions come from the regional background.
- Approximately, 50 % of the $PM_{2.5}$ composition is related with **traffic**. However, the main contribution of this sector is not the exhaust gases but rather tire and brake wear and particle resuspension which means that even zero-emission cars would still aggravate the air quality inside the cities. Reduction of road traffic would have a positive impact in public health, since incomplete combustion of fossil fuel produces elemental carbon particles, which act as carrier for other toxic compounds.
- Atmospheric aerosol is mainly produced by **traffic, industry and agriculture**. Its stability and transformations depends, among other parameters, on availability of other chemical species and temperature.
- **Households** should be considered when thinking about measures to reduce the amount of total carbon in the cities. Their contribution ranged between 7 % in Thessaloniki and 17 % in Ljubljana. In Madrid households contributed the least (5 %) around all cities in Europe considered in ICARUS.
- **Waste treatment and disposal** as well as **non-road transport** do not play an important role as sources of $PM_{2.5}$ as their contributions in all cities are lower than 3 % for the former and lower than 2 % for the latter. Only in Thessaloniki non-road transport showed a slightly higher contribution (3 %) due to shipping and port activities.