Current knowledge on the concentration of Airborne Nanoparticles in outdoor areas

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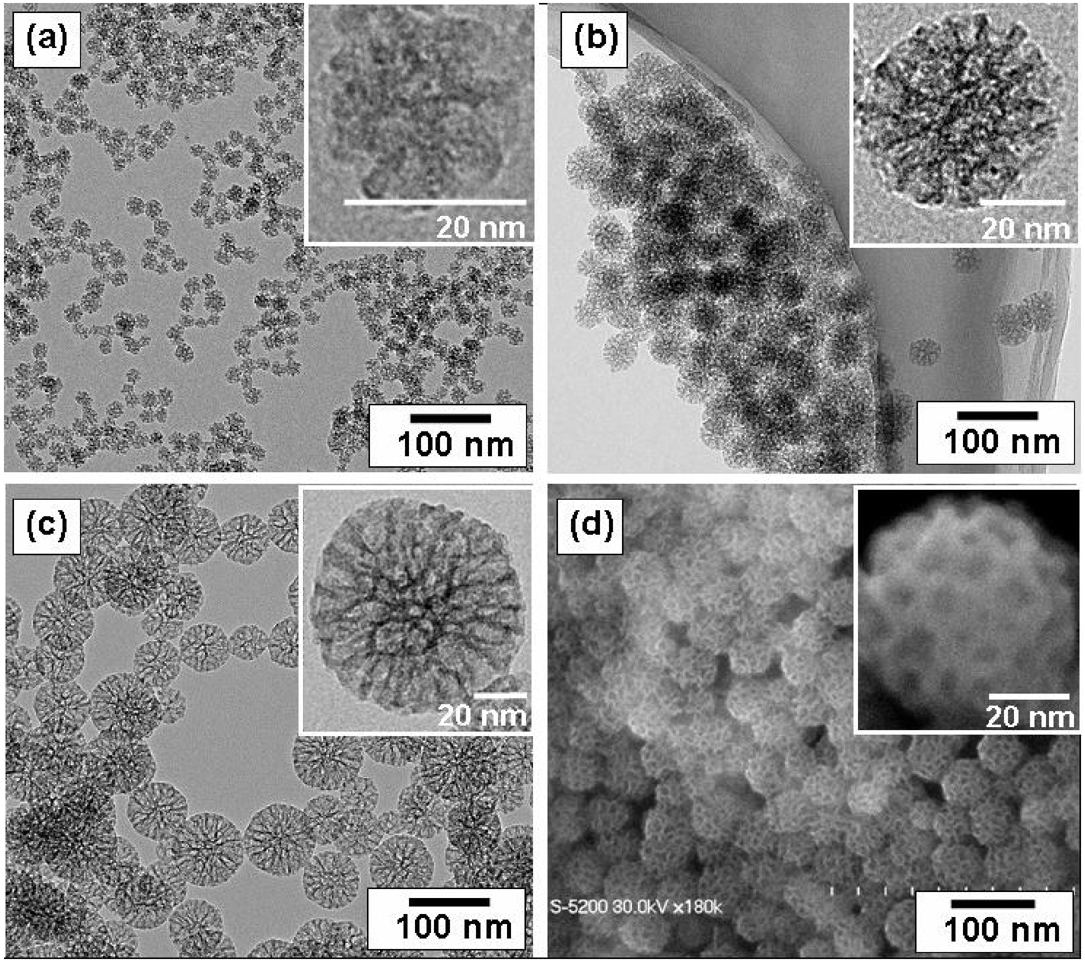
Nanomaterial:

A natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm - 100 nm

(European Commission recommendation2011/696/EU)

What does it look like?



Transmission electron microscopy TEM (a, b, and c) images of prepared mesoporous SILICA NANOPARTICLES with mean outer diameter: (a) 20nm, (b) 45nm, and (c) 80nm. Scanning electron microscope SEM (d) image corresponding to (b)

Where do they come from?

Natural sources

- Mineral dust
- Sea spray aerosols
- Biogenic emissions
- Volcanic eruptions
- Lightning

Anthropogenic sources

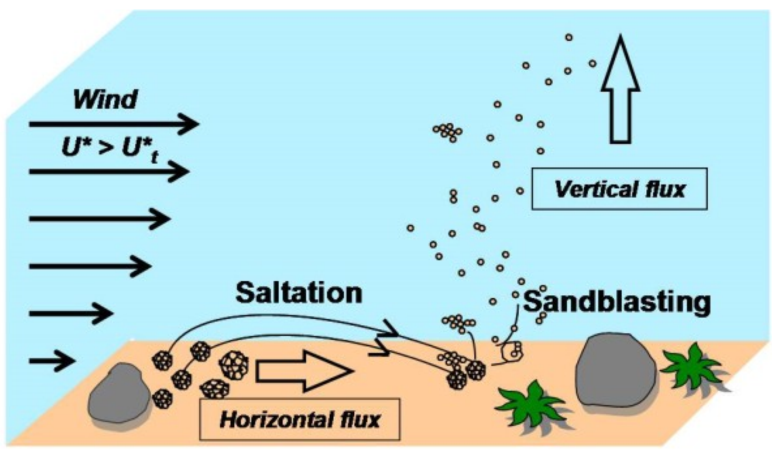
- Traffic
- Industrial activities
- Coal burning
- Biomass burning
- Food cooking
- Garbage burning
- Tobacco
- Fireworks

A.I. Calvo et al., 2013

Natural sources

1- Mineral dust

The main mechanism for producing small dust particles is sandblasting from saltating particles



Origin:

- Deserts
- Dry lake beds
- Semi-arid surfaces

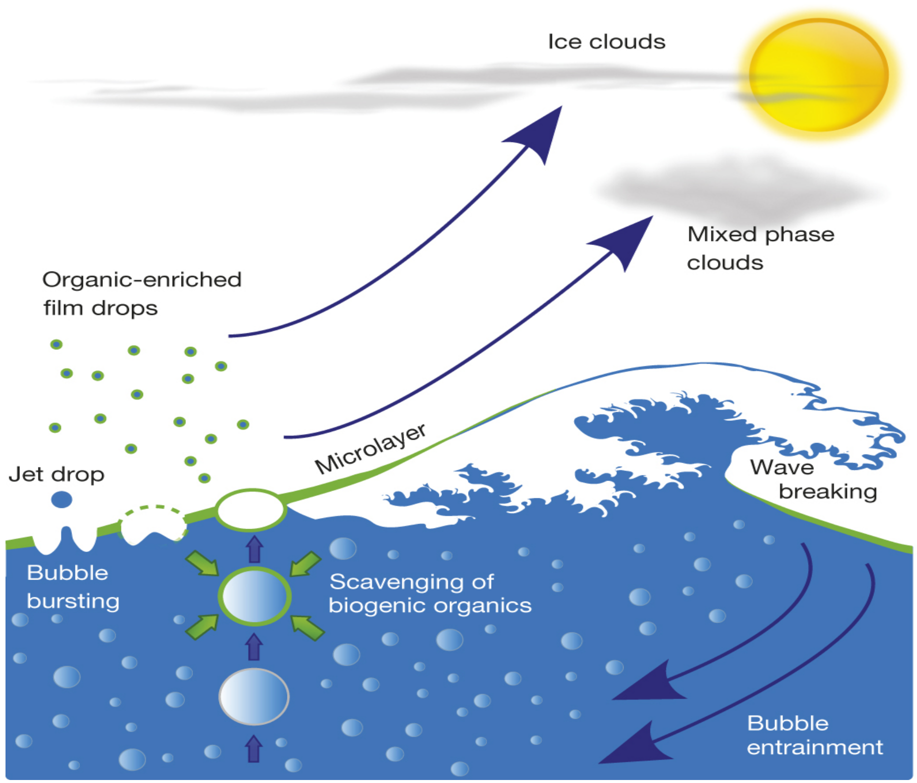
Regulation Factors:

- Wind Speed
- Precipitation
- Soil surface
- Soil moisture
- Vegetation cover

Natural sources

2- Sea spray aerosols

Marine aerosol is the most important aerosol fraction worldwide. Primary marine aerosols are formed by the eruption of rising bubbles through the sea-surface microlayer

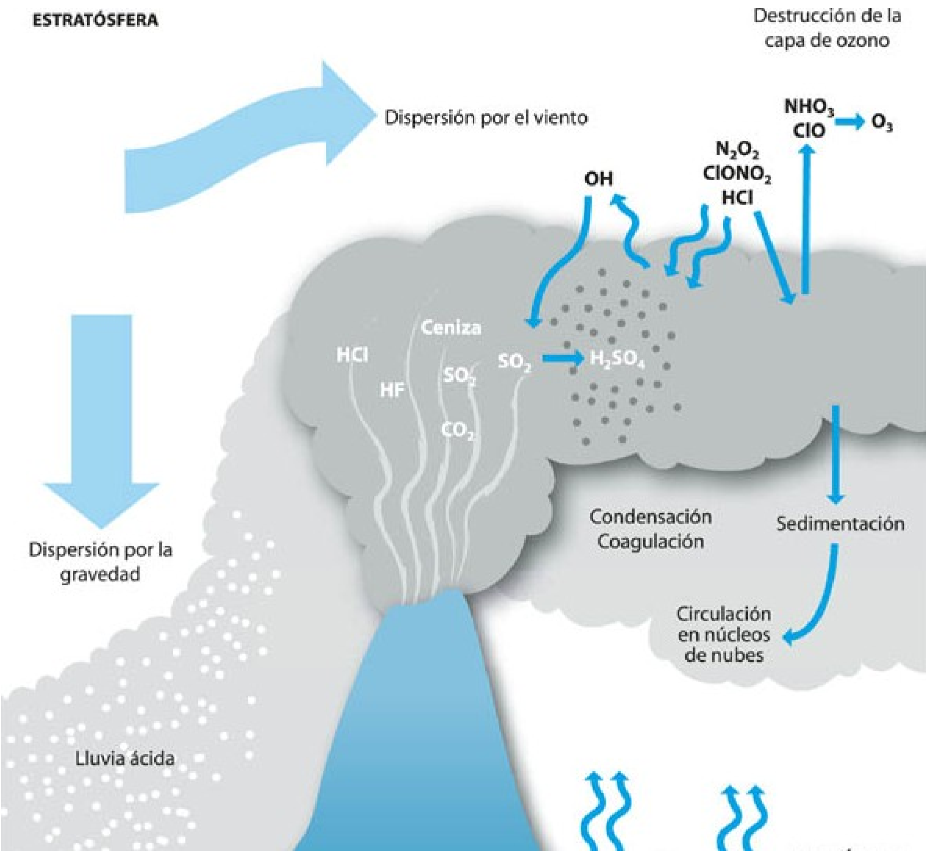


Main regulation factor:

- Wind Speed

Natural sources

3- Volcanic eruptions



Natural sources

3- Volcanic eruptions

- 1-2 x 10^9 kg of SO_2 per eruption can be released to the atmosphere, becoming a sulphate aerosol precursor (Corradini et al., 2010, Haywood et al, 2010)
- Al, Si, S, Cl, K, Ca, Ti,Mn, Fe, Cu, and Zn are part of its chemical composition (Allard et al., 2000)
- On average, volcanoes and geothermal activities release about $9x10^4$ Kg yr^{-1} of mercury to the atmosphere (Mason 2009)

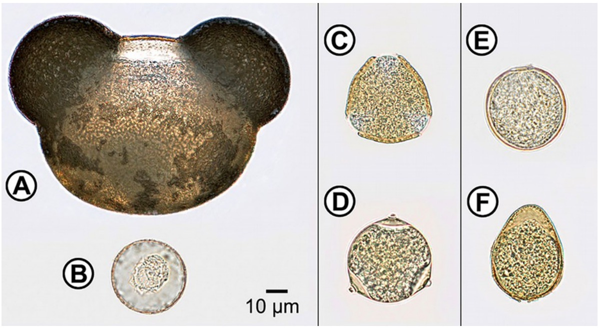
Natural sources

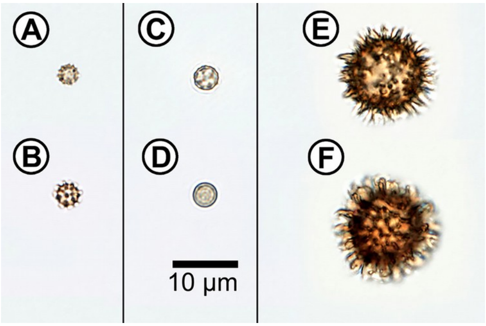
4- Lightning

- It is an important source of NO_x (NO and NO_2) in the atmosphere, which made lightning a source of secondary natural nitrate particles (Schumann and Huntrieser, 2007)
- An estimated value of about 5×10^9 Kg (N) yr^{-1} has been widely accepted for lightning N production

Natural sources

5- Biogenic emissions





- Pollen
- Fern spores
- Fungal spores
- Small fragments and excretions from:

  plants, animals, bacteria, viruses, carbohydrates, proteins, waxes or ions

Anthropogenic sources

1- Traffic

Road traffic

- Exhaust and non-exhaust sources (particles from brake wear, tyre wear, catalytic converters, road surface abrasion and resuspension in the wake of passing traffic), contribute approximately equal amounts to the total traffic-related emissions (Querol et al. 2014)

Heavy duty vehicles	20–730 x 10^{13} nanoparticles vehicle^{-1} km^{-1}*
Light duty vehicles	2–70 x 10^{13} nanoparticles vehicle^{-1} km^{-1}*
Road–tyre interface emissions	3.7–32 x 10^{11} nanoparticles vehicle^{-1} km^{-1}**

* Beddows and Harrison, 2008 ** (50-70 km/h^{-1}) Dahl et al., 2006

Anthropogenic sources

Railway traffic

- Rail-wheel interaction makes iron particles predominat (67%)
- Aluminium and calcium particles coming from the abrasion of the gravel bed and the resuspension of mineral dust contribute 23% and 10% (Lorenzo et al., 2006)

Anthropogenic sources

Air and maritime traffic

- Air traffic contibutes to the emissions with BC, OC, NO_X and SO_X. Moreover, aircraft engines are emitters of metal particles (Al, Ti, Cr, Fe, Ni, and Ba)
- Ships release SO_2 (16% of the global sulphur emissions) (Corbett and Fischbeck, 1997), NO_x (~70 g NO_x kg^{-1} of fuel burned) and carbonaceous particulate matter (1.33 x 10^8 Kg yr^{-1}) (Lack et al., 2007; Gaffney and Marley, 2009)

Anthropogenic sources

2- Industrial activities

There is a wide range of industrial activities emitting to the atmosphere particulate matter or precursors of particles

Emitted particles depend on:

- Production process
- Technology
- Raw materials used

Main elements associated to every activity:

- Mining operations → As, Cd, Pb
- Foundries → Ni, Va, Mn, Cu and SiO_2 in the emitted fly ashes
- Steel plants → Fe_2O_3
- Cement plants → CaO
- Coal power plants → SiO_2 in the emitted fly ashes
- Energy production from fossil fuels → gases acting as aerosol precursors

Anthropogenic sources

3- Coal burning

- In developing countries, residential coal combustion plays an important role
- Emissions are influenced by factors such as coal maturity, coal combustors or burning conditions
- It is an important source of gases and atmospheric particulate matter worldwide

Anthropogenic sources

4- Biomass burning

- It includes burning of woodland, pastures and agricultural land after harvesting activities
- The aerosols generated by biomass burning consist mainly of carbonaceous compounds, and most of the particles emitted have a count median diameter of 100–150 nm (Badarinath et al., 2009)
- It is an important source of gases and atmospheric particulate matter worldwide
- Around 38x10^6 metric tones of $PM_{2.5}$ are emitted per year (Alves et al., 2011)

Anthropogenic sources

4-1- Wildfires

Between 80% and 90%of the particles generated by biomass burning has a diameter smaller than 1 μm (Alonso-Blanco et al., 2012)

Their characteristics will depend on:

- Type of fuel
- Humidity
- Combustion phase
- Wind conditions

Anthropogenic sources

4-2- Domestic biomass burning

In winter, especially in rural sites, a considerable number of household stoves are used having an important potential to contribute to atmospheric pollution

Emissions will depend on:

- Stove design
- Operating conditions
- Combustion conditions
- Species of wood

(Johansson et al., 2003)

Anthropogenic sources

4-3- Agricultural burning

The burning of agricultural crop residues in fields represents a regular part of the annual agricultural activities of farmers worldwide and is considered the fourth most important type of global biomass burning

Emissions estimation:

- 500 x 10^6 metric tons of dry matter per year

(Andreae and Merlet, 2001; Bond et al., 2004)

- 13 g of particulate matter and 19 g of NO_x per kg of burnt dry cereal waste

(Ortiz de Zárate et al., 2000)

Anthropogenic sources

5- Food cooking

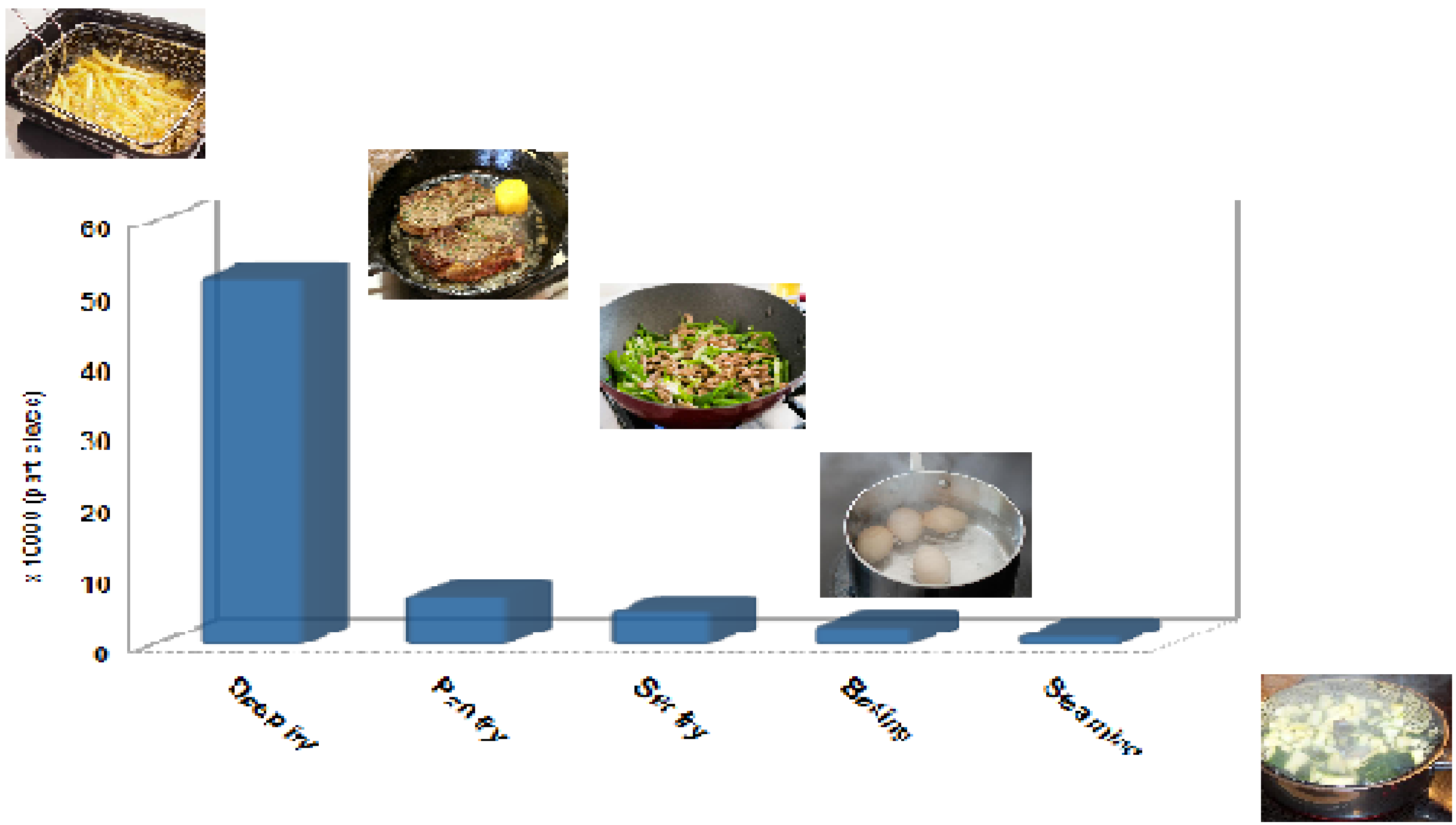
It is another major source of particles in urban areas and cover from ultrafine to coarse range

Main emission factors:

- Cooking temperature
- Cooking method
- Cooking apliances
- Cooking ingredients

Anthropogenic sources

5- Food cooking



(See and Balasubramanian, 2008)

Anthropogenic sources

6- Garbage burning

Garbage composition:

- Biomass
- Plastic
- Paper
- Textile
- Rubber/Leather
- Glass
- Metals

Garbage burning is not included in most inventories because it is usually illegal. However, roughly half of the garbage generated globally (~10^9 metric tons yr^{-1}), may be burnt in open fires or incinerators (Christian et al., 2010)

Anthropogenic sources

6- Garbage burning

Since garbage acts as an heterogeneous fuel, particles emitted from garbage burning cover a wide range:

- $PM_{2.5}$
- Black Carbon
- Organic Carbon
- Metals

(Christian et al. 2010)

- Levoglucosan
- Mannosan
- Galactosan
- HCl, which is not observed in biomass burning is registered in important concentrations in garbage burning emissions

Anthropogenic sources

7- Tobacco

- Environmental tobacco smoke is a complex mixture of gases and particles estimated to contain more than 4000 individual chemical constituents
- Fresh undiluted cigarette smoke contains large amounts of potentially toxic nanoparticles <50 nm (Van Dijk WD et al., 2011)
- Tobacco is a small source contributing organic fine particulate matter to the outdoor urban atmosphere, being cigarette smoke accounted for about 2.7% of the fine organic aerosol emissions in Los Angeles (Rogge et al., 1994)

Anthropogenic sources

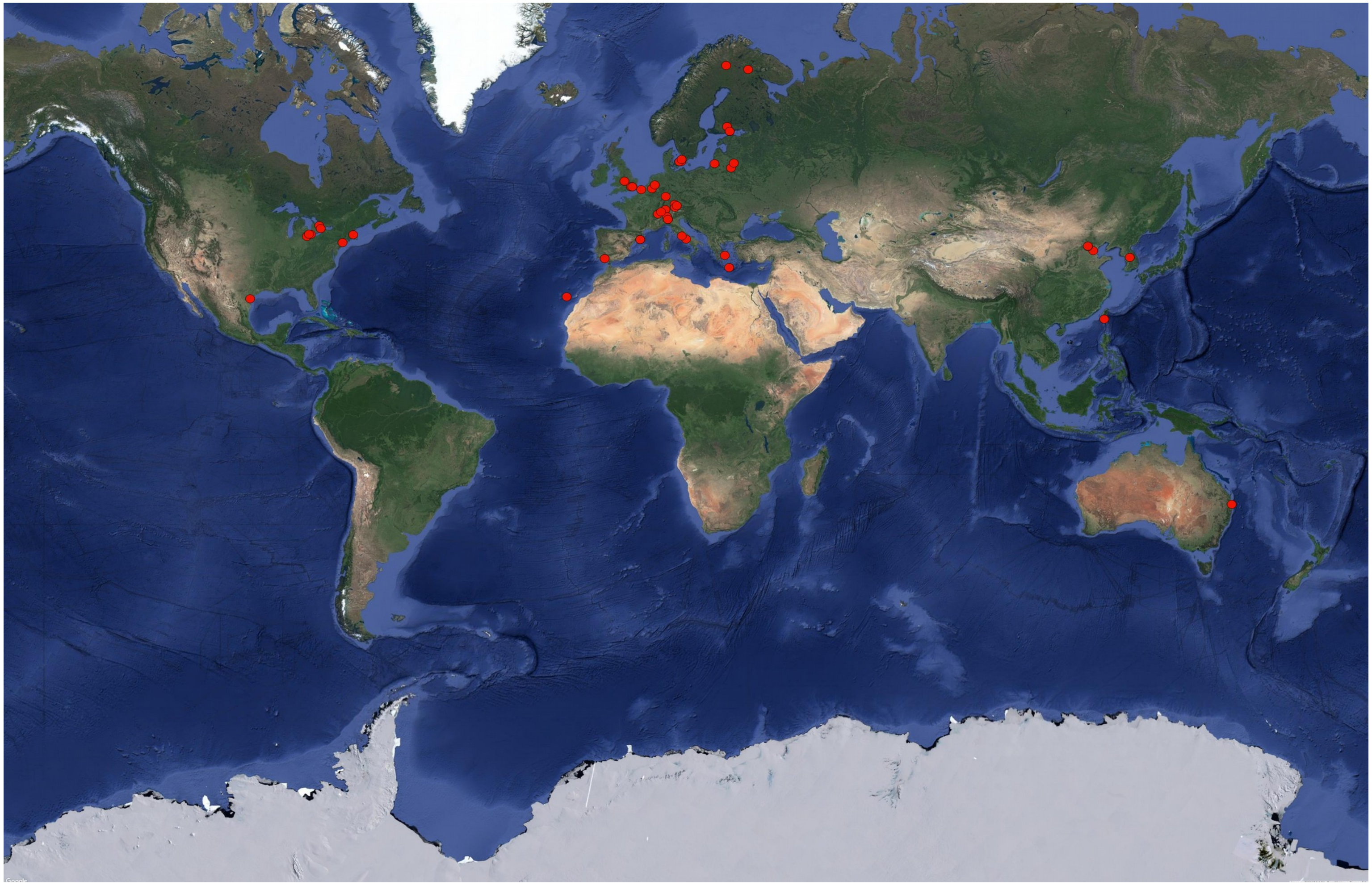
8- Fireworks

- Although transient, fireworks constitute an important source of gases (ozone, sulphur dioxide, nitrogen oxides), particles (mainly metals: Sr, K, Ba, Co, Pb, Cu) and organic compounds, creating considerably short-term air pollution

Evaluation of information sources

Information has been compiled from more than 50 scientific papers. All of them include measurements of particle concentrations or/and distributions, always covering UFP range

Data source locations



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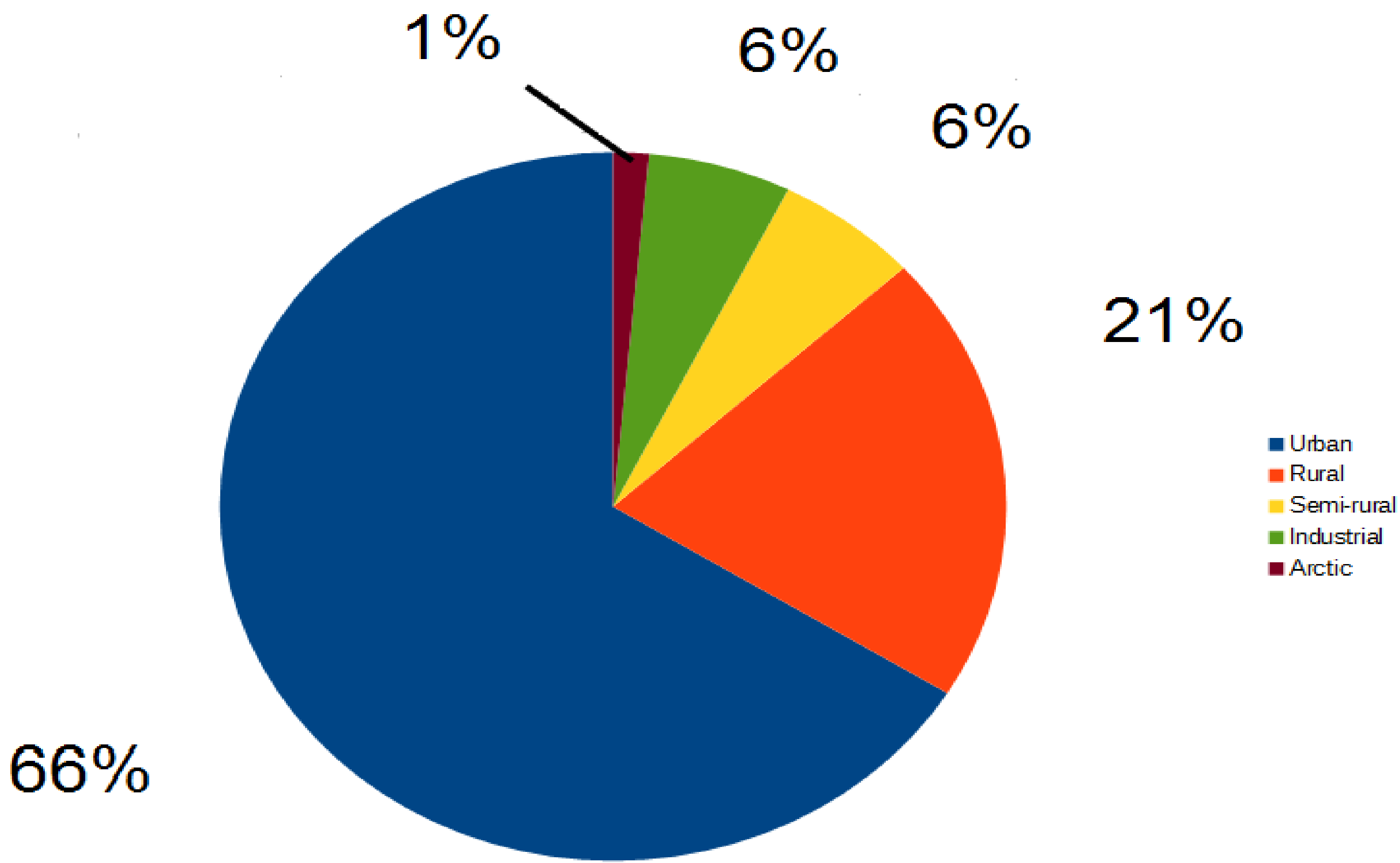
Environments distribution



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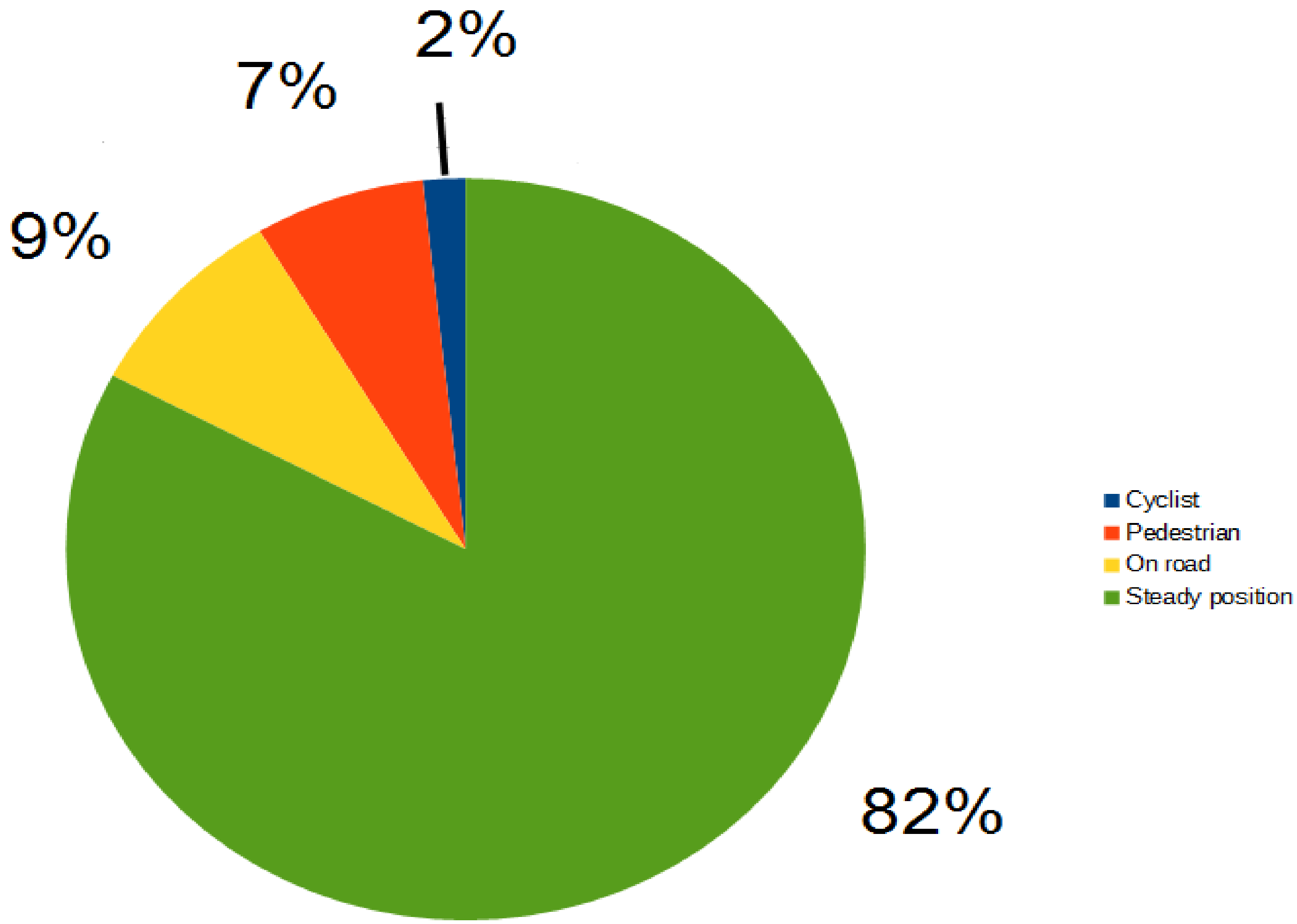
Methodology



Typical concentrations

The table shows values for UFP amog other variables obtained in different studies for road urban scenario and its urban background

City (locations)	This study (2012) (Seoul, Korea)	Westerdahl *et al.* (2005) (Los Angeles, USA)	Kittelson *et al.* (2004a, b) (New York[c], Minnesota[d], USA)	Schneider *et al.* (2008) (Aachen, Germany)
Roadway average				
UFPs (1000 s/cm^3)		55–200 (F)[a]	200–560 (F)[c]	140 ± 48 (F)
	97 ± 18 (A)	40 (A)[b]	160 (A)[c]	133 ± 15 (A)
BC (µg/m^3)		2.4–20 (F)		3.2 ± 2.5 (F)
	7.4 ± 2.5 (A)	1.5 (A)		13.6 ± 3.2 (A)
PM-PAHs (ng/m^3)				
	98 ± 28 (A)			
NO_x (ppb)		230–470 (F)		
	203 ± 56 (A)	140 (A)		
NO (ppb)		120–470 (F)	100–240 (F)[c]	
	133 ± 33 (A)	79 (A)		
CO_2 (ppm)		800–900 (F)	400–420 (F)[c]	
	633 ± 12 (A)	720 (A)		
Background				
UFPs (1000 s/cm^3)	60 ± 29	14–27	9[d]	
BC (µg/m^3)	5.4 ± 0.6	0.4–1.6		1.5 ± 9.3
PM-PAHs (ng/m^3)	30.6 ± 46.4			
NO_x (ppb)	86 ± 67.4	35–50	15[d]	
NO (ppb)	51.6 ± 78.0	14–19		
CO_2 (ppb)	583.6 ± 10.2	368–475	364[d]	

[a] indicates “Freeway”. [b] indicates “Arterial roadway”, [c] indicates study in New York, [d] indicates study in Minnesota.
± indicates standard deviations of measured concentrations.

Kim et al., 2015

Thanks for your attention!