The PMF project; towards magnetic and chemical characterisation of urban PM sources and associated early-health effects

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Intro | Urban particulate matter

Urbanization in Manhattan
Intro | Urban particulate matter

Vietnam

Urbanization in Manhattan
Intro | Urban particulate matter

Vietnam

India

Urbanization in Manhattan
Intro | Urban particulate matter

1/8 = 7 million deaths

2012’ world mortality

World Health Organization
Mixture of µm-size particles suspended in the air with a wide range in size and chemical composition.
Introduction | Urban particulate matter

Mixture of μm-size particles suspended in the air with a wide range in size and chemical composition.
Air PM concentrations

Air quality monitoring stations offer limited spatial monitoring due to high investment and maintenance costs

Biomonitoring

“Measurement of the response of living organisms to air quality of their surroundings”

“biomonitoring as a powerful, cost effective, user friendly, tool for filling the gap between the causes and effects of environmental pollutants, as bioindication agents assess the cumulative effects of pollution” (Nali & Lorenzini, 2007)

→ Human, plants & animals: e.g. Stress-related gene expression, Mosses, POP’s in bird feathers
Air PM concentrations

**Air quality monitoring stations** offer **limited spatial monitoring** due to high investment and maintenance costs

**Biomagnetic monitoring of urban plant leaves**

- Magnetic properties of leaves
- Ferrimagnetic fraction of PM: $\propto$ iron oxides ($\text{Fe}_3\text{O}_4$ vs $\text{Fe}_2\text{O}_3$, ...)
- Traffic-related sources: combustion or metallic abrasion (engine and brake disks)
Intro | Leaf biomagnetic monitoring

- SIRM: Saturation Magnetization ($M_s$)
- High field susceptibility ($\chi_{HF}$)
- Low field susceptibility ($\chi_{LF}$)
- Coercivity ($H_C$)
- Remanence coercivity ($H_{RC}$)

Particle composition
Grain size indicator
Biomagnetic Monitoring of Atmospheric Pollution: A Review of Magnetic Signatures from Biological Sensors

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ABSTRACT: Biomagnetic monitoring of atmospheric pollution is a growing application in the field of environmental magnetism. Particulate matter (PM) in atmospheric pollution contains readily measurable concentrations of magnetic minerals. Biological surfaces, exposed to atmospheric pollution, accumulate magnetic particles over time, providing a record of location-specific, time-integrated air quality information. This review summarizes current knowledge of biological material (“sensors”) used for biomagnetic monitoring purposes. Our work addresses the following: the range of magnetic properties reported for lichens, mosses, leaves, bark, trunk wood, insects, crustaceans, mammal and human tissues; their associations with atmospheric pollutant species (PM, NOx, trace elements, PAHs); the pros and cons of biomagnetic monitoring of atmospheric pollution; current challenges for large-scale implementation of biomagnetic monitoring; and future perspectives. A summary table is presented, with the aim of aiding researchers and policy makers in selecting the most suitable biological sensor for their intended biomagnetic monitoring purpose.
How does the amount and composition of PM deposited on *Platanus acerifolia* leaves change across different cities in Europe? Environ. Sci. Technol.
**Magnetic- and particle-based techniques to investigate metal deposition on urban green.** Sci. Total Environ.

Baldacchini et al., 2017
How does the amount and composition of PM deposited on *Platanus acerifolia* leaves change across different cities in Europe? Environ. Sci. Technol.
Intro | Biomagnetic fingerprinting

Air quality monitoring and modelling applications

Spatio-temporal variation

Source apportionment

AIRbezen Oost-Vlaanderen 2017 – citizen science project
No straightforward relation between magnetic parameters and PM load and/or composition when including multiple sources.

Source-dependent magnetisable composition

![Diagram showing magnetic response and land use classes]
Health relevance of biomagnetic monitoring in urban environments

Atmospheric PM - Magnetic properties

Health-related PM compounds (HM, UFPs, BC, PAHS)

Early-health effects (pro-inflammatory response)

Biomagnetic-based fingerprinting of PM sources
Methodology

**AIR SAMPLING**
- Leckel SEQ47/50
- PM (Dusttrak II), BC (AE51), UFP (P-Trak)
- Magnetic properties (Leckel)
- ED-XRF (Leckel)
- SEM-EDX (Leckel)
- HR-ICP-MS (Leckel)
- GCxGC-TOFMS (Leckel)

**SOURCE SAMPLING**
- Tissues
- Magnetic properties
  - SEM-EDX
  - HR-ICP-MS

**LEAF SAMPLING**
- Ivy leaves
  - Magnetic properties
  - ED-XRF
  - SEM-EDX
  - HR-ICP-MS
  - GCxGC-TOFMS

**ACUTE HEALTH EFFECTS**
- Coriolis
  - Pro-inflammatory markers of U937 lung cells
  - mRNA expression IL8, IL1-β and TNFα
Methodology pre-campaign

- Test planned analyses on leaf & filter surfaces
  - ED-XRF, HR-ICP-MS, SEM-EDX, magnetic properties
- Test plant species (Hedera sp., Fragaria sp.)
- Test accumulation period needed

3 plants per species next to air quality monitoring station
12th of May – 4th of August, 2017
Blank – 3w – 6w – 9w – 12w
Results pre-campaign

0 weeks  Strawberry leaves  6 weeks

adaxial

abaxial
Methodology PMF project

PMF Campaign:

16th of September–7th of November, 2017

5 locations: 4 PM sources – 1 background

Continuous gravimetric PM$_{10}$ sampling (Leckel SEQ 47/50)

Weekly sampling:
- Point measurements PM$_{10}$ (Dusttrak), UFP (P-Trak) and BC (AE51)
- Coriolis: pro-inflammatory response/oxidative potential biomarkers

Leaf sampling: 16 ivy leaves (0w–3w-7.5w)
Monitoring sites - Background
Monitoring sites – Road traffic

• Downwind of E34 (Antwerp – Turnhout)
• Vorselaar
Monitoring sites – Railway traffic

- Antwerp-Mechelen traject
- Rechtstraat, Duffel
Monitoring sites – Shipping

• Deurganckdok, Antwerp harbor
• Tidal dock
• DP World - Antwerp Gateway
Monitoring sites – Industry

• Metal recycling plant
• Umicore, Hoboken
• VMM 40HB23
Monitoring sites – Industry

- Metal recycling plant
- Umicore, Hoboken
- VMM 40HB23
Weekly point measurements

PM$_{10}$, UFP and BC

Coriolis
Weekly point measurements

$PM_{10}$, UFP and BC

Rain wash out – a real time observation
Filter-magnetic properties $\propto$ PM load

Linear fit
$R^2 = 0.28$ (n = 210)
P < 0.0001

Linear fit
$R^2 = 0.44$ (n = 210)
P < 0.0001
Leaf SIRM as bio-indicator for cumulative PM filter load

- Average leaf SIRM ($A$) vs. Cumulative PM filters load (mg)

The relationship can be described by the equation:

$$y = 6E-05x + 0.0008$$

with an $R^2$ value of 0.7432.
Results are still coming in; nevertheless...

- Accumulation & elemental analysis have proven suitable using ivy leaves over 6 weeks
- PM load: 🚣‍♂️ > 🚗 > 🏟️ > 🚣‍♂️>
- Magnetic PM: 🚗 > 🚗 > 🏟️ > 🚣‍♂️ > 🌾
- Filters: Magnetic properties $\sim$ PM$_{10}$ mass
  - source-specific
- Leaves: Magnetic properties $\sim$ cumulative atmospheric PM$_{10}$
- Different inflammatory responses observed for different sources (e.g. Shipping vs Background)
Thank you!

BIOMAP 8

2-7 July 2018
Dubna, Russia

More info --> ResearchGate!