MACRO TRACER MODEL AS A TECHNIQUE FOR SOURCE APPORTIONMENT OF PARTICULATE MATTER IN KRAKOW AGGLOMERATION – AN OPTIMIZATION APPROACH

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ATMOSPHERIC AEROSOLS

- Dispersion of liquid or solid particles suspended in the air
- PM is present both in the troposphere and the stratosphere; the particles vary in size and chemical composition
- PM has an impact on the global climate, ecosystems and human health as well

PM classification due to the aerodynamic diameter (AD) size:
- PM$_{2.5}$ – with AD ≤ 2.5 um;
- PM$_{10}$ – with AD ≤ 10 um;
- TSP (Total Suspended Particles) – all aerosols, even with AD larger than 10 um.

Fig. 1. Comparison of particles PM$_{2.5}$ and PM$_{10}$ sizes to the size of the hair or sand.
EMISSION SOURCES OF ATMOSPHERIC AEROSOLS

Fig. 2.
RECEPTOR MODELS

Receptor models are mathematical procedures used to identify the sources of pollutant emissions and to estimate their contribution in the overall balance of atmospheric aerosol emissions based on measurements of the concentrations of aerosol components, without the need to carry out an inventory of emission sources or data describing meteorological conditions. The concept of a macro tracer model consists in determining a chemical compound - an indicator or tracer, which is specific to a given source.

I. Positive matrix factorisation
II. Chemical mass balance
III. Macro tracer
THE BASIS OF
MACRO TRACER MODEL

\[ PM_{grav} = \sum_{k=1}^{p} F_{jk} c_{jk} + c_{N/A} \]

- \( k \) numerator of emission sources
- \( F_{jk} \) the coefficient of \( k^{th} \) emission source correcting the concentration of \( j^{th} \) PM component
- \( c_{jk} \) the concentration of \( j^{th} \) PM component being the tracer of \( k^{th} \) emission source
- \( c_{N/A} \) the concentration of the non-identified PM fraction.
IS IT POSSIBLE TO IDENTIFY THE EMISSION SOURCES OF PM ON THE BASIS OF ITS CHEMICAL COMPOSITION?
WHAT WAS NECESSARY TO PROCEED?

SAMPLING OF PARTICULATE MATTER ON QUARTZ FIBRE FILTERS IN REPRESENTATIVE AREAS

THE QUALITATIVE IDENTIFICATION OF PARTICULATE MATTER ORIGIN ON THE BASIS OF ITS CHEMICAL COMPOSITION - MASS CLOSURE MODEL

THE CHEMICAL CHARACTERISATION OF SOLID PARTICLES EMITTED FROM DIFFERENT SOURCES

THE QUANTITATIVE IDENTIFICATION OF PM ORIGIN IN KRAKOW AGGLOMERATION WITH AN APPLICATION OF OPTIMIZED MACRO TRACER MODEL
THE QUALITATIVE IDENTIFICATION OF PARTICULATE MATTER ORIGIN – MASS CLOSURE

Combustion processes
Secondary inorganic aerosols
Resuspension dust
Road salt

Styszko, K., Kistler, M., Szramowiat, K., Nowak, M., Kasper-Giebl, A., Golaś, J., Seasonal variations of chemical composition of two aerosol size fractions at urban and rural site in South Poland. (Unpublished).
MAIN COMPONENTS OF PM

Carbonaceous compounds

OC, EC

Cations

Anions

NO₃⁻, SO₄²⁻, NH₄⁺, Cl⁻, K⁺, Ca²⁺, Mg²⁺, Na⁺

Metals, metalloids

Al, Fe

Lewoglukozan

Sugars, anhydrosugars

Hg, As
MACRO TRACER MODEL OPTIMISATION TO THE REGION WITH DOMINATING ROLE OF COAL AS AN ENERGY SOURCE

MACRO TRACER MODEL

THE CHEMICAL CHARACTERISATION OF SOLID PARTICLES EMITTED FROM DIFFERENT SOURCES

THE QUANTITATIVE IDENTIFICATION OF PM ORIGIN IN KRAKOW AGGLOMERATION WITH AN APPLICATION OF OPTIMIZED MACRO TRACER MODEL

Macro tracer assumptions

Estimation of new F coefficients

Correlation of obtained results $PM_{grav}$ vs. $PM_{MT}$
<table>
<thead>
<tr>
<th>Emission Source</th>
<th>Tracer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrial Coal Combustion</strong></td>
<td>As</td>
</tr>
<tr>
<td><strong>Other Industrial Processes</strong></td>
<td>Ca, Fe_{ind}</td>
</tr>
<tr>
<td><strong>Wood Combustion</strong></td>
<td>Lewoglukozan</td>
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<tr>
<td><strong>Coal Combustion</strong></td>
<td>Hg/OC</td>
</tr>
<tr>
<td><strong>Culm Combustion</strong></td>
<td>K^+</td>
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<tr>
<td><strong>ECO-PEA Combustion</strong></td>
<td>K^+</td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td>EC</td>
</tr>
<tr>
<td><strong>Road Dust</strong></td>
<td>EC</td>
</tr>
</tbody>
</table>
EMISSION SOURCE

SECONDARY INORGANIC AEROSOLS
ALUMINOSILATES, CARBONATES
ROAD SALT
NON-IDENTIFIED ORGANIC MATTER

TRACER

$\text{NH}_4^+, \text{SO}_4^{2-}, \text{NO}_3^-$
$\text{Ca, Al, Si, Fe}_{\text{rest}}$
$\text{Na}^+, \text{Cl}^-$
$\text{OC}$
MACRO TRACER MODEL OPTIMISATION TO THE REGION WITH DOMINATING ROLE OF COAL AS AN ENERGY SOURCE

- Macro tracer assumptions
- Estimation of new F coefficients
- Correlation of obtained results $\text{PM}_{\text{grav}}$ vs. $\text{PM}_{\text{MT}}$
THE QUANTITATIVE IDENTIFICATION OF PM ORIGIN WITH MACRO TRACER

PM10

URBAN_WINTER  URBAN_SUMMER  RURAL_WINTER  RURAL_SUMMER

SALT  MIN  SECONDARY AER  ECO  CULM  COAL  WOOD  R. DUST  INDUST.  EXH.  COAL INDUSTRY  OMND  N/A
THE QUANTITATIVE IDENTIFICATION OF PM ORIGIN WITH MACRO TRACER

Kraków - PM10

- 11.02.2013
- 18.02.2013
- 27.02.2013

μg m⁻³

SALT  MIN  SECONDARY AEROSOLS  ECO-PEA  CULM  COAL  WOOD  ROAD DUST  EXHAUSTS  INDUSTRY  COAL INDUSTRY  OMND  N/A
PM10 gravimetrically measured vs. PM10 estimated with macro tracer

Rural - summer

$r^2 = 0.8968$

Urban
winter: $0.8606$
summer: $0.8899$

Rural
winter: $0.7553$
summer: $0.8968$
CONCLUSIONS

• The Macro Tracer model enables the identification of particulate matter emission sources.
• The application of Macro Tracer model confirmed the so far obtained conclusions that particulate matter mainly originates from combustion processes of different fuels.
• The further work is necessary:
  • To characterize particulate matter from higher amount of emission sources or
  • To focus on more specific components, like PAHs, or their nitric or oxygen derivatives
• Macro tracer model is a promising tool for easy and fast identification of particulate matter origin.
THANK YOU FOR YOUR ATTENTION!

For more questions, please contact me at:
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