



University of Zilina



Faculty of Civil Engineering

Department of Highway Engineering



ECTRI – FEHRL – FERSI

Young Researchers Seminar 2015

June 17 – 19, 2015 in Rome, Italy



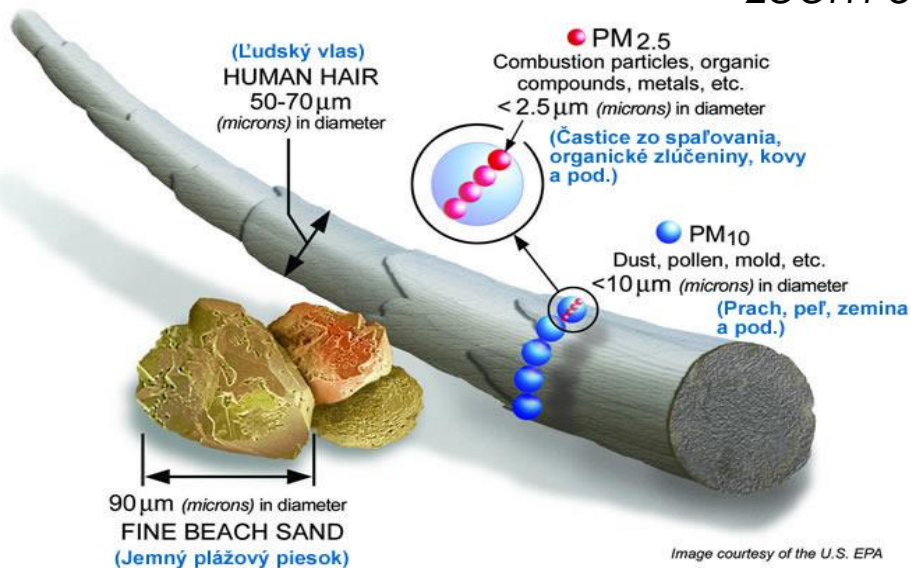
Road transport as the
primary source of
particulate matter in the
ambient air in urban and
non-urban areas of
northern Slovakia

Dusan Jandacka

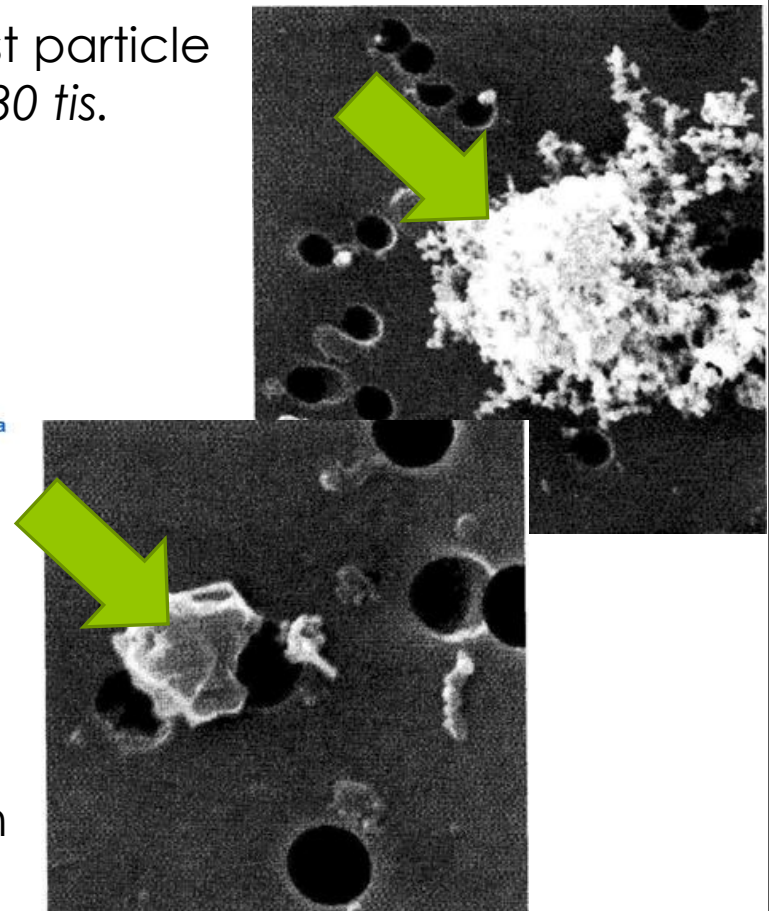
- Particulate matter
- Monitoring and chemical analysis of particulate matter
- Identification process of particulate matter sources
 - Urban area
 - Non-urban area
- Conclusions

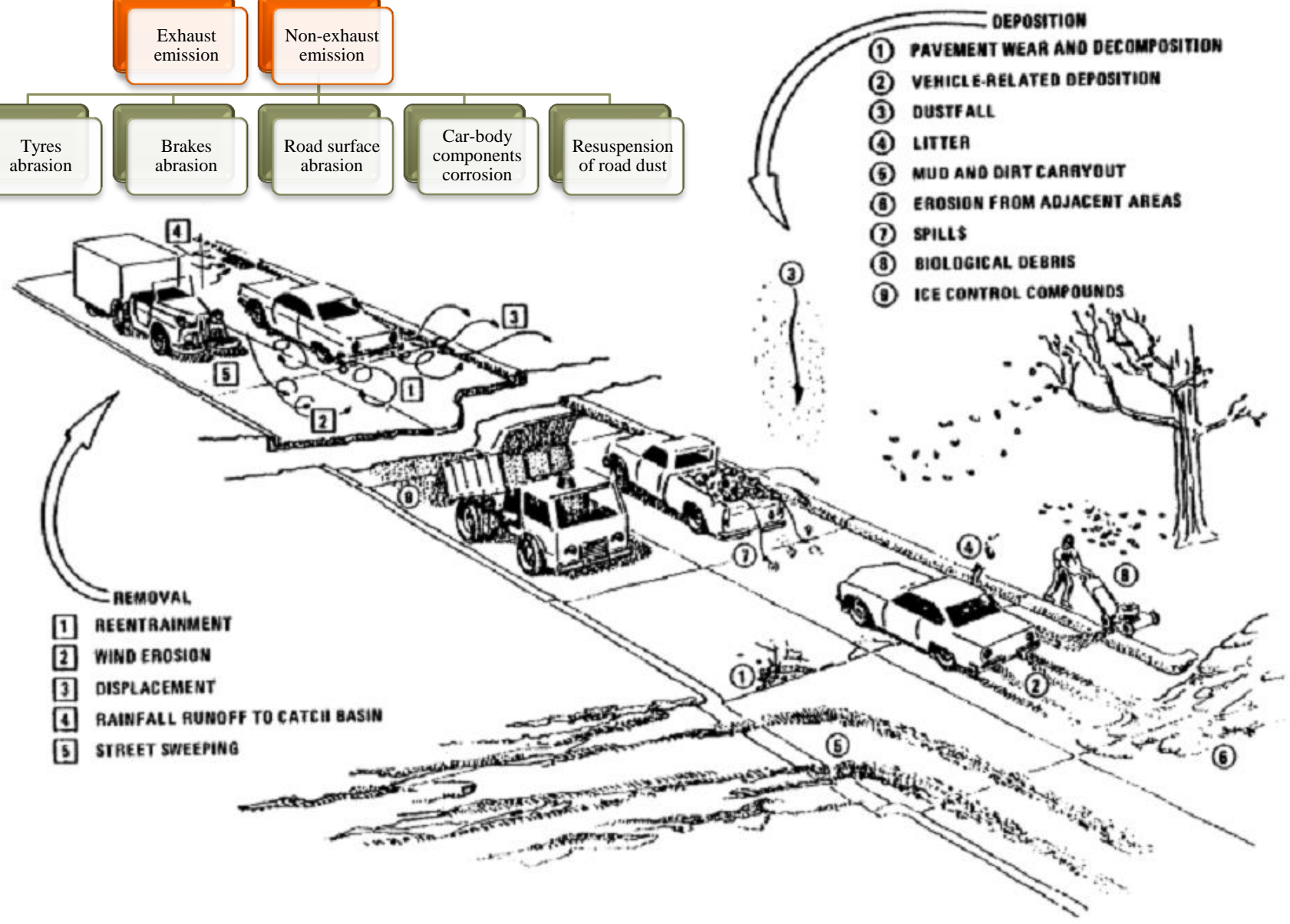
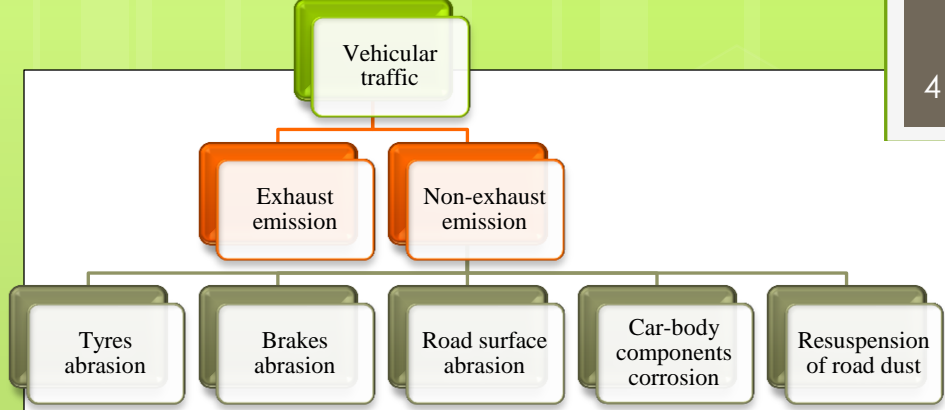
- **Course fraction** – aerodynamic diameter $2,5 - 10 \mu\text{m}$ ($\text{PM}_{2,5-10}$) – mechanical abrasion and removal of road dust.
- **Fine fraction** – aerodynamic diameter $< 2,5 \mu\text{m}$ ($\text{PM}_{2,5}$) – chemical reactions, condensation of exhaust emissions, coagulation of ultrafine particles.

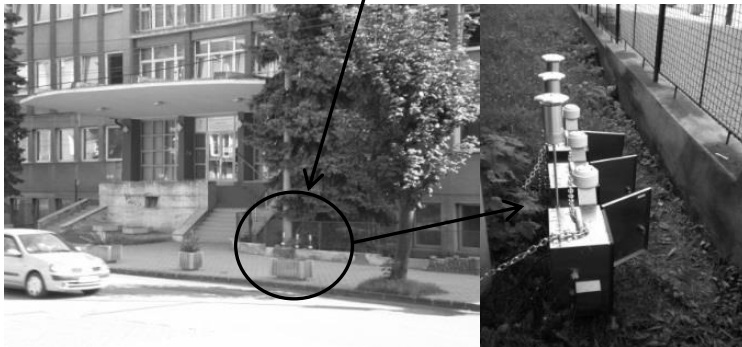
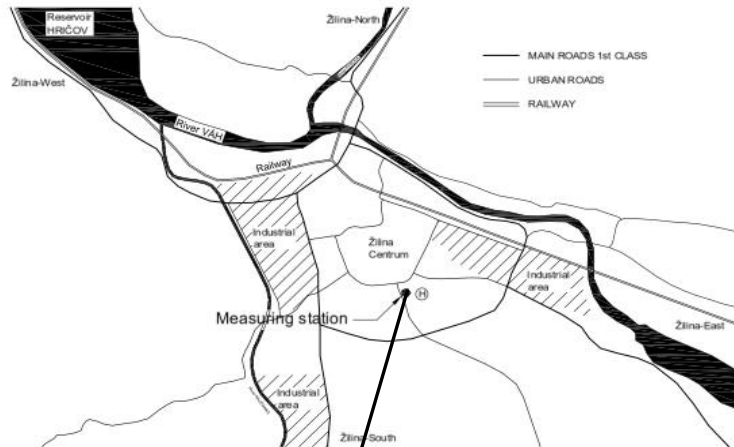
Exhaust particle
zoom 30 tis.



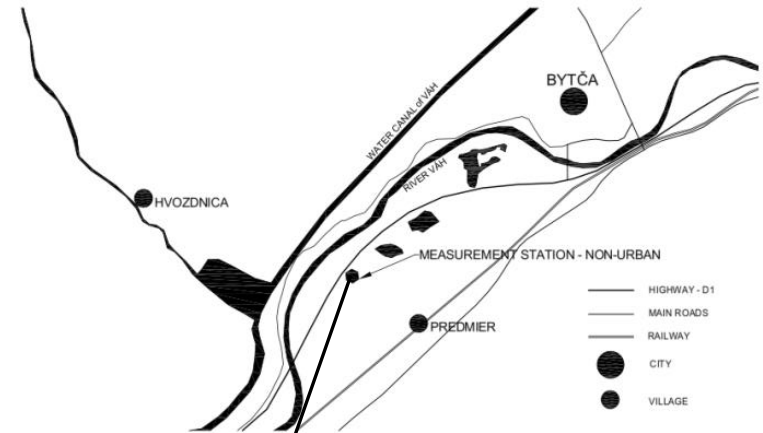
Particle from mechanical abrasion
zoom 70 tis.



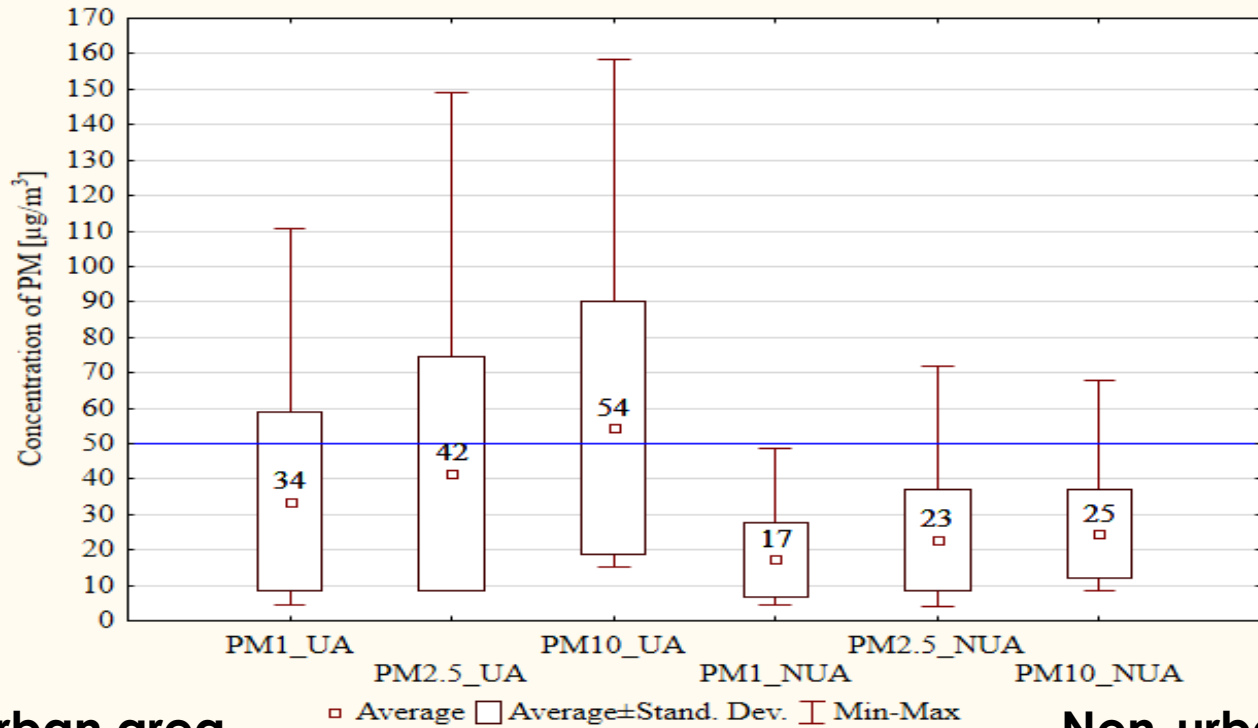




- in the urban area in the vicinity of an urban road in the City of Žilina,
- during the years 2010 – 2012,
- 8 measuring cycles were realized,
- total of 56 measurements were performed,
- Urban area is typically city canyon.

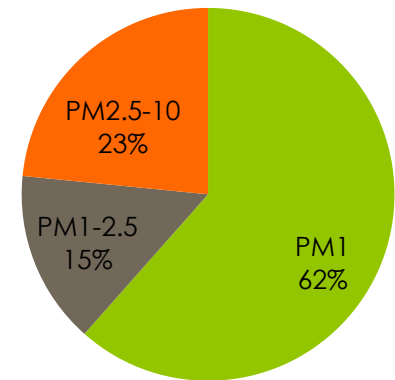
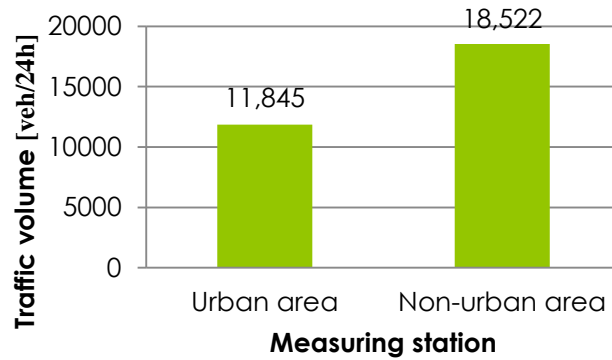
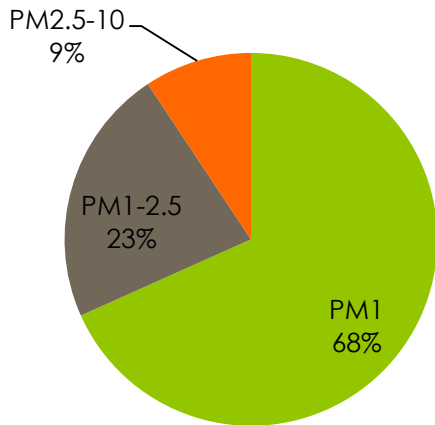


- in the non-urban area in the vicinity of a highway D1
- during the years 2013 – 2014,
- 3 measuring cycles were realized,
- total of 36 measurements were performed,
- surroundings of Non-urban area - open area with agro land and water areas.



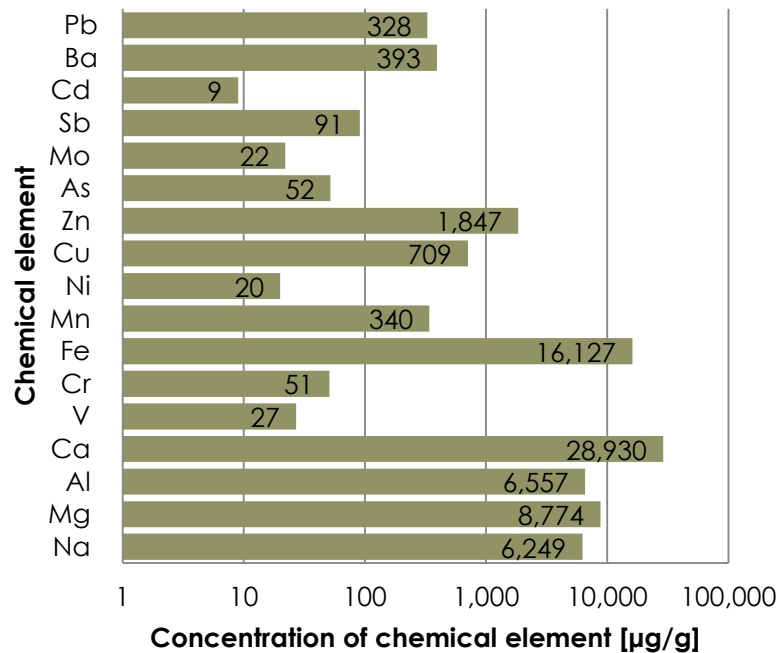
Urban area

Non-urban area

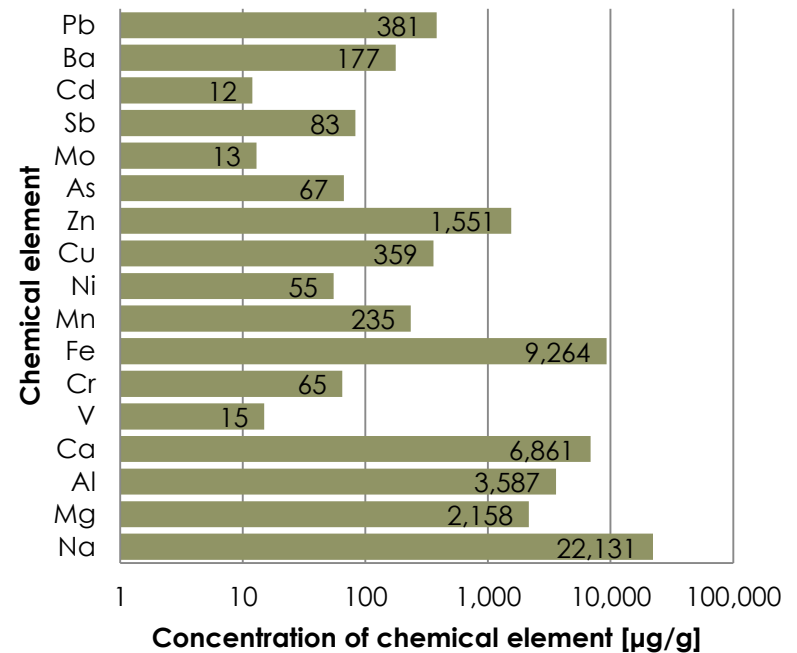


In order to determine the amount of chemical elements in the sample of particulate matter (PM_{10}) the spectroscopic methods (inductively coupled plasma mass spectrometer ICP MS) were utilized.

The average concentration of chemical elements in the urban area



The average concentration of chemical elements in the non-urban area



- Each of these metals may come from a specific source (Table).
- Based on a sufficiently comprehensive database of data it deems possible by the utilization of multi-layer statistical methods (for instance factorial analysis), to more closely specify the possible source of this particulate matter.

Source		Associated elements	
Transportation	road surface	Al, Si, Ca, Mg, C, Na, K, V, Ni	
	car-body components	Cu, Sn, Cr, Pb, Cd, As, Sb, Fe, Al	
	brake callipers, pads and rotors	Cu, Sb, Ba, Cr, Fe, Ni, Pb, Zn	
	tyres	Zn, Cd, Pb, Cu, Ni, Fe, Mn, Cr, Co	
	fuel and lubricating oil	diesel	Al, Ca, Mg, Mn, Cu, Fe, Mo, V, Zn
		gasoline	Sr, Cu, Mn
		oil	Fe, Ca, P, Zn, Mg
	catalytic converter	Pt, Pa, Rh (Platinum metals)	
road dust	Zn, Al, K, Fe, Na, Mn		
Burning coal and wastes		Zn, Sb, Cu, Cd, Hg, Se, As, Cr, Co, Al	
Industry		Sb, Ag, V, Ni, As, In, Cu, Mn, Ce, Co, Cr, Pb	
Biomass burning		K	
Incinerators		Cd, Pb, Sb, Zn	

$$y_k = \sum_{j=1}^m v_{kj} x_j$$

where: y_k principal components, $k = 1, \dots, p$,
 x_j former character, input variable, $j = 1, \dots, m$,
 v_{kj} coefficients of own vectors.

Matrix notation:

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_p \end{bmatrix}_{p \times 1} = \begin{bmatrix} v_{11} & \cdots & \cdots & v_{1m} \\ v_{21} & \cdots & \cdots & v_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ v_{p1} & \cdots & \cdots & v_{pm} \end{bmatrix}_{p \times m} \times \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{bmatrix}_{m \times 1}$$

- The primary goal of PCA is the transformation of the original characters of x_j , $j=1, \dots, m$, into a smaller amount of latent variables of y_k .
- The first principal component y_1 describes the greatest part of variability.

$$X_j = \sum_{k=1}^p \lambda_{jk} F_k + E_j$$

where: λ_{jk} factor load of the j -th object to the k -th common factor
 F_k , $j = 1, \dots, m$, $k = 1, \dots, p$,
 F_k the k -th common factor,
 E_j is a random deviation, $j=1, \dots, m$.

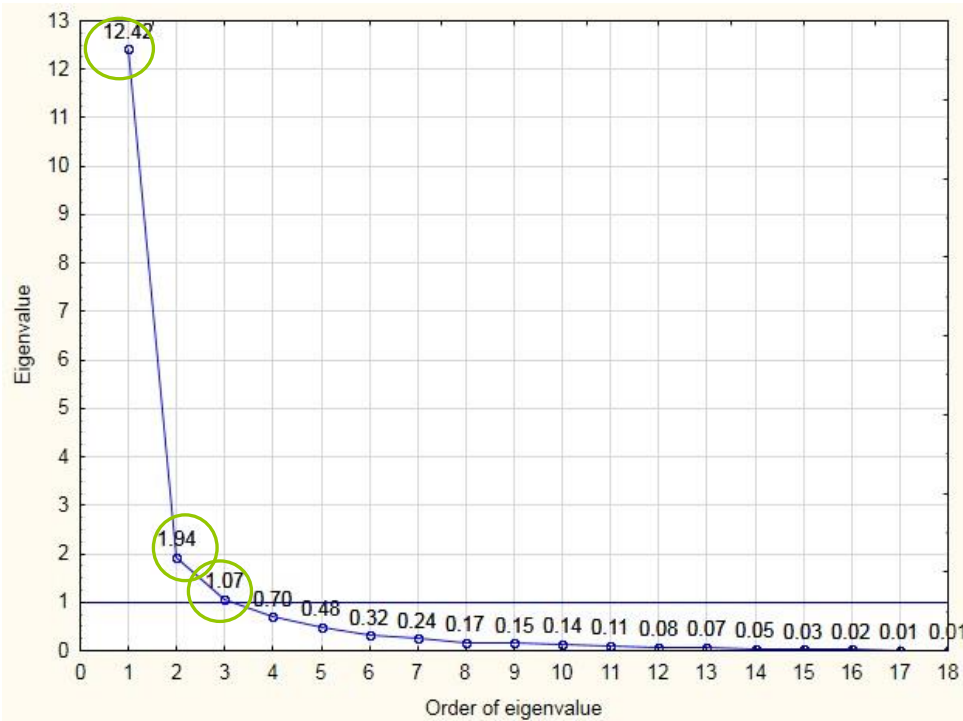
Matrix notation:

$$\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{bmatrix}_{m \times 1} = \begin{bmatrix} \lambda_{11} & \lambda_{12} & \cdots & \lambda_{1p} \\ \lambda_{21} & \lambda_{22} & \cdots & \lambda_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ \lambda_{m1} & \cdots & \cdots & \lambda_{mp} \end{bmatrix}_{m \times p} \times \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_p \end{bmatrix}_{p \times 1} + \begin{bmatrix} e_1 \\ e_2 \\ \vdots \\ e_m \end{bmatrix}_{m \times 1}$$

- The fundamental principle of factor analysis lies in the fact that each and every of monitored values X_j ($j = 1, \dots, m$) may be expressed as a sum of a linear combination of a lesser amount p non-observed (hypothetical) random values F_1, \dots, F_p – so called common factors and the further source of variability E_j ($j = 1, \dots, m$) – so called specific (residual) elements.

- Using a data matrix was compiled from the concentrations of selected metals in ng/m^3 (Na, Mg, Al, Ca, Cu, Sb, Ba, Pb, Cd, Cr, As, Mo, V, Mn, Fe, Ni, Zn) and PM_{10} in $\mu\text{g}/\text{m}^3$ resulting from 8 measurement cycles between the years of 2010 and 2012. The data matrix contained 18 variables and 56 objects.

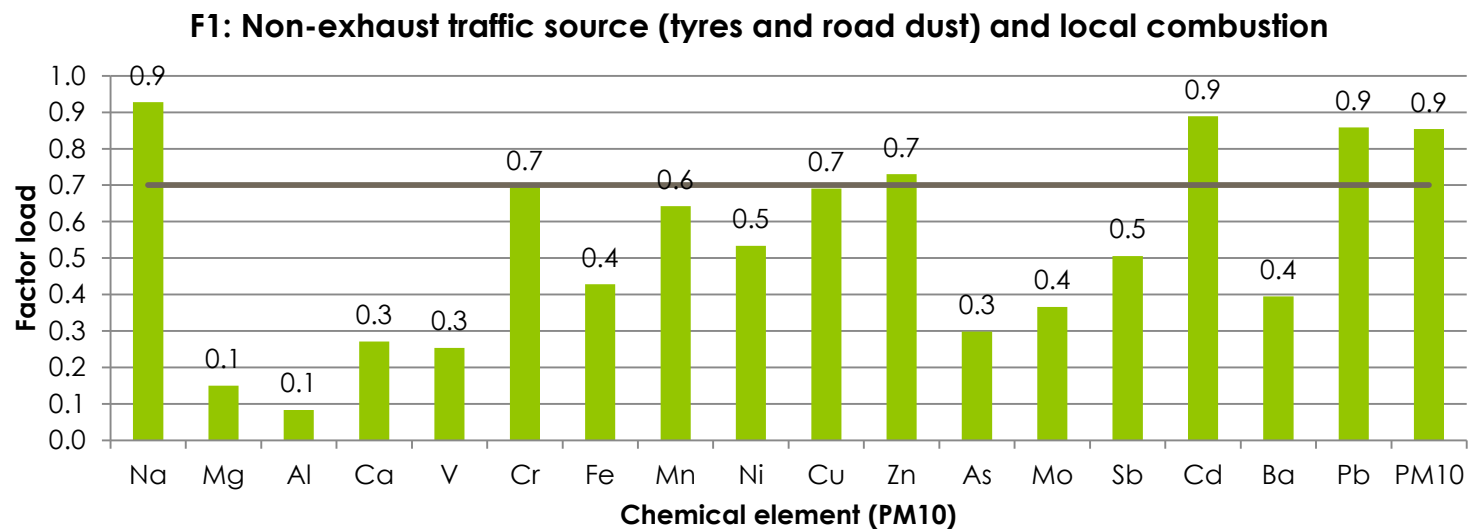
PCA

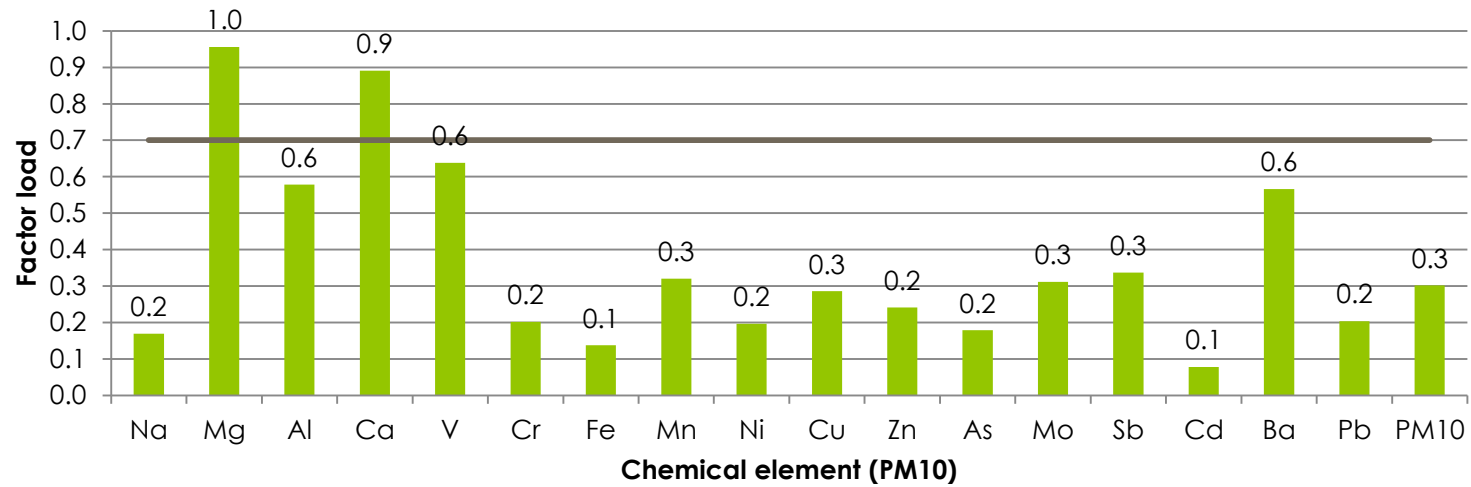
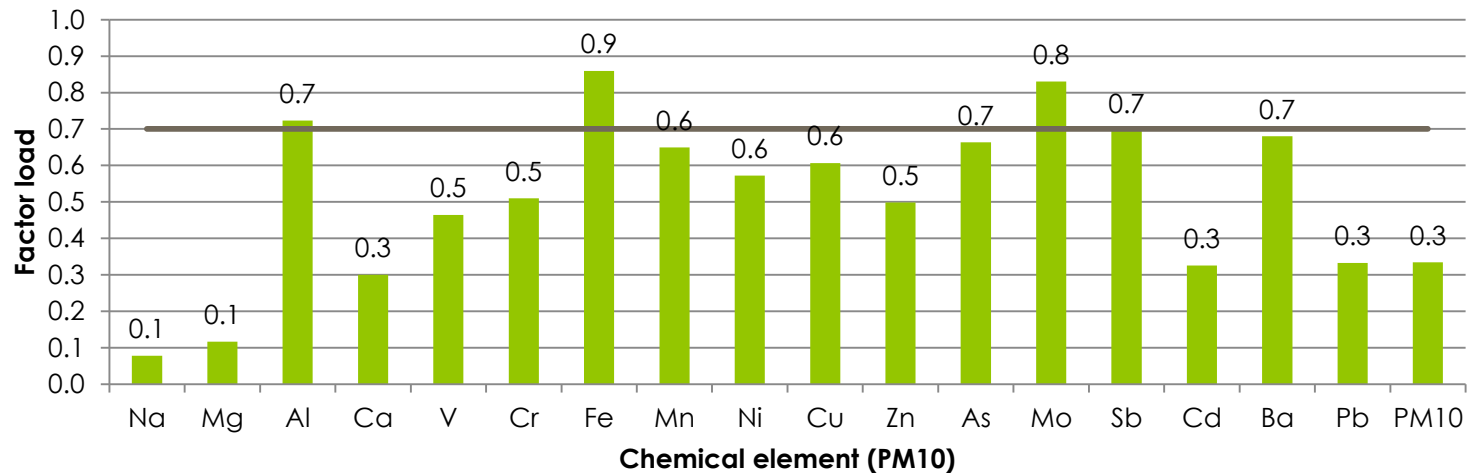


Pursuant to the rate of eigenvalues (1 – **12.42**, 2 – **1.94**, 3 – **1.07**) there were **3** main components selected (selection criteria of eigenvalue > 1.0). The three main components define **85.70 %** of the total dissipation, spread of the former characters.

FA

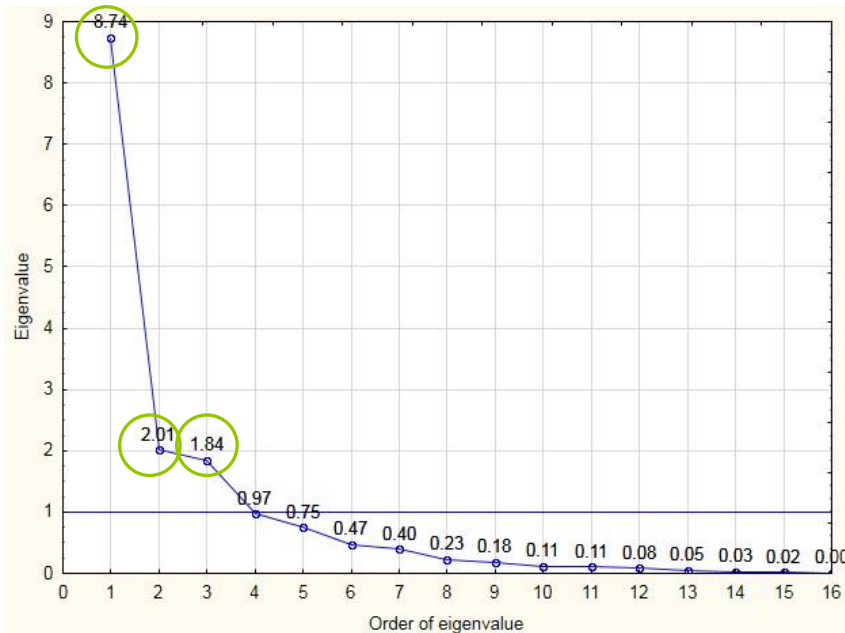
- 3 factors were selected for the factor analysis.
- the factor loads are quoted in relation to particular characters and particular factors. They may be explained as the correlation between the factors and characters. They represent the most important unit of information the interpretation of factors is based on.



F2: Exhaust traffic source - diesel fuel, lubricating oil**F3: Non-exhaust traffic source - brakes, car-body, road surface**

- Using a data matrix was compiled from the concentrations of selected metals in ng/m^3 (Na, Mg, Al, Ca, Cu, Sb, Ba, Pb, Cd, As, Mo, V, Mn, Fe, Zn) and PM_{10} in $\mu\text{g}/\text{m}^3$ resulting from 3 measurement cycles between the years of 2013 and 2014. The data matrix contained 16 variables and 36 objects

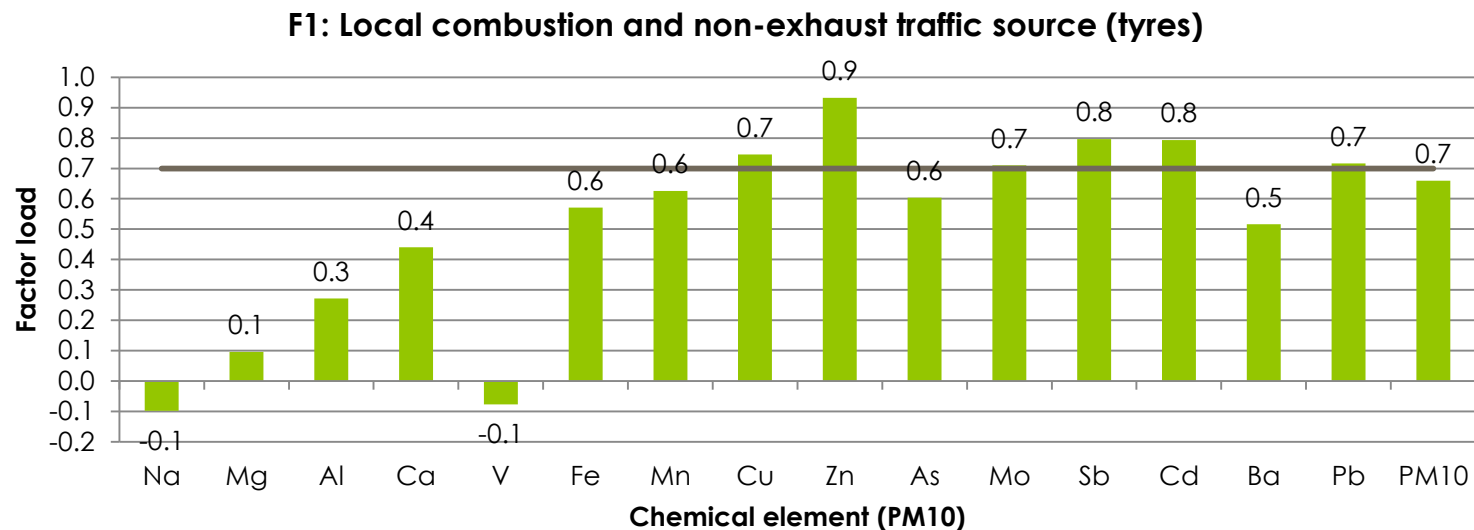
PCA

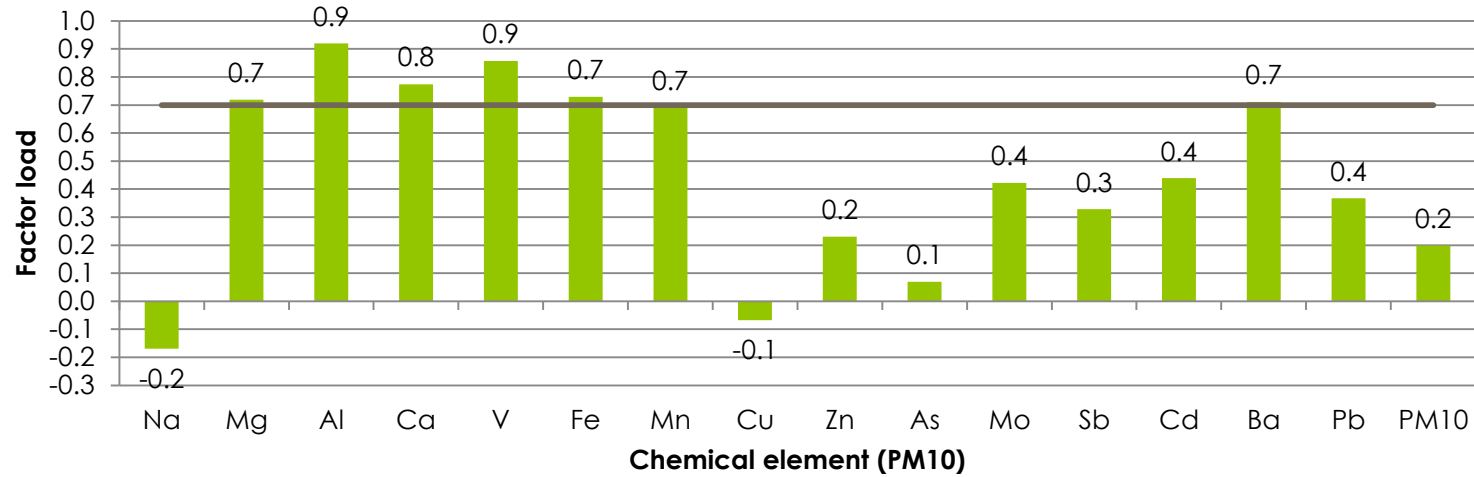
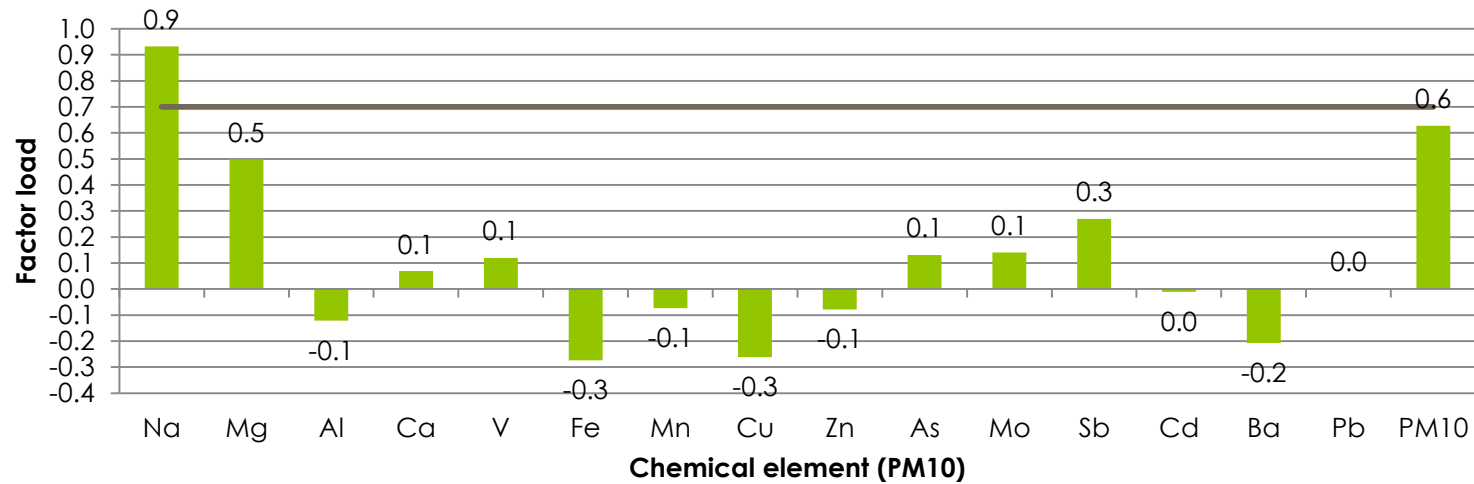


Pursuant to the rate of eigenvalues (1 – 8.74, 2 – 2.01, 3 – 1.84) there were 3 main components selected (selection criteria eigenvalue > 1.0). The three main components define **78.71 %** of the total dissipation, spread of the former characters.

FA

- 3 factors were selected for the factor analysis.
- Individual elements are broken down into three factors after performing the FA. These factors were named on the basis of the elements involved.



F2: Exhaust traffic source - diesel fuel, lubricating oil and earth crust**F3: Road dust - winter salting**

- The average concentrations of PM were **twice higher** in Urban area like in Non-urban area,
- Traffic volume – Urban area **11,845** [veh/24h], Non-urban area **18,522** [veh/24h],
- The highest concentration of chemical element: **Ca** – Urban area, **Na** – Non-urban area,
- The lowest concentration of chemical element: **Cd** – both areas,

- Urban area: Factor 1 - **Non-exhaust traffic source (tires and road dust) and local combustion**, Factor 2 - **Exhaust traffic source - diesel fuel, lubricating oil**, Factor 3 - **Non-exhaust traffic source - brakes, car-body, road surface**.
- Non-urban area: Factor 1 – **Local combustion and non-exhaust traffic source (tyres)**, Factor 2 – **Exhaust traffic source – diesel fuel, lubricating oil and earth crust**, Factor 3 – **Road dust – winter salting**.
- Usability of method - identification of sources of particulate matter in specific risk areas,
- Following this analysis - determining the contribution of each named sources to the formation of PM.

...thanks for your attention

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