Emission of heavy metals and solid particles from domestic wood combustion processes

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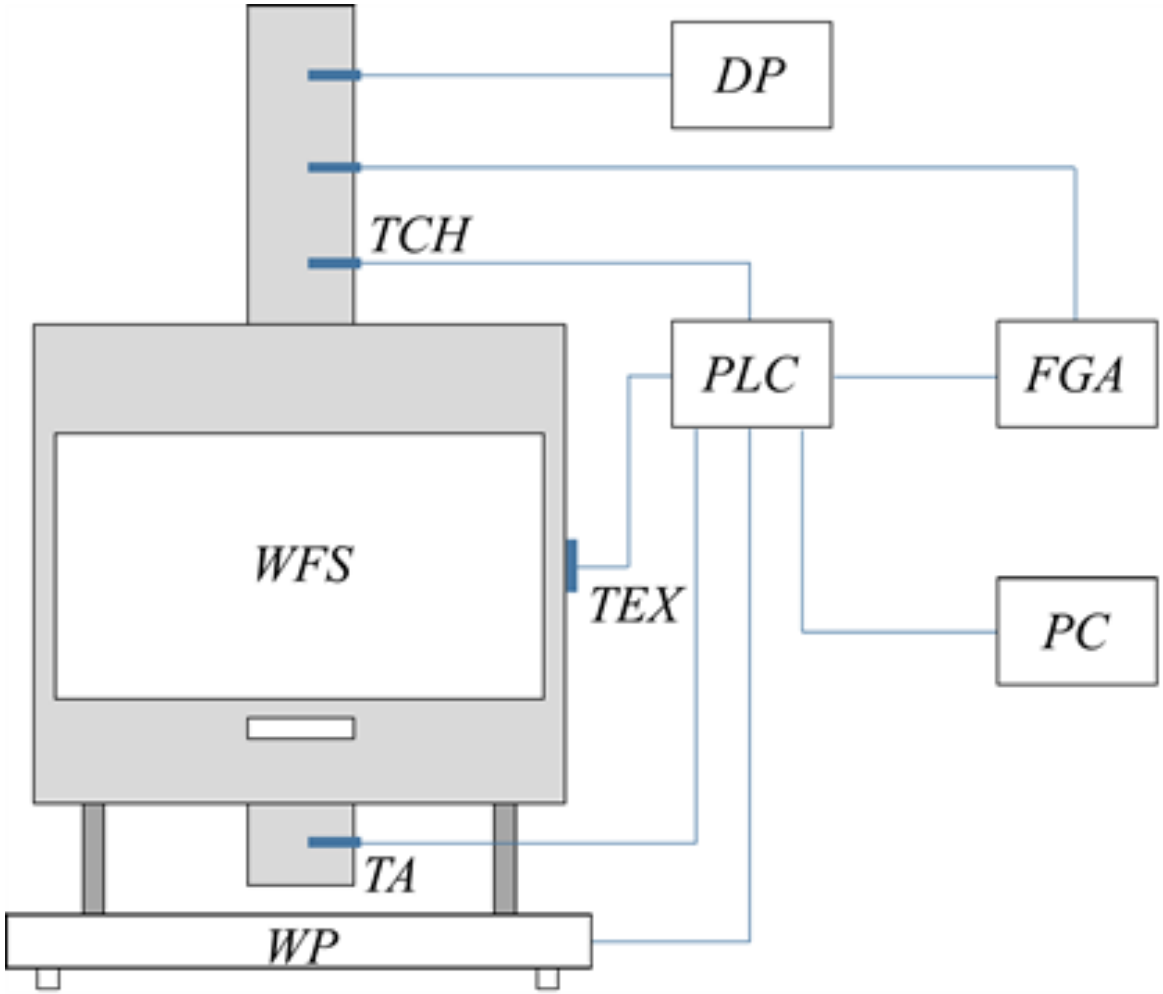
Outline

1. Introduction
2. Experiment conducting
3. Results
4. Conclusions

Introduction

The configuration of the experimental stove



WFS - wood-fired stove
WP - weighting platform
FGA - flue gas analyzer
PLC - PLC controller
TCH - thermocouple sensor
TEX - resistance sensor
TA - thermoanemometer
DP - dust probe
PC - computer

The experiment: FUEL

Chemical characteristics of the biomass fuel

	Spruce		
Ultimate analysis (wt %)		Cork	Wood
	C_{ad}	39.6	46.2
	H_{ad}	5.40	7.45
	S_{ad}	0.05	0.01

- » C_{ad} – carbon in the air-dried basis
- » H_{ad} – hydrogen in the air-dried basis
- » S_{ad} – sulphur in the air-dried basis

- In total 20 kg of logwood was burned in a single experiment, split up in five batches.
- A total experimental time lasted 4 hours

The experiment: BURNING

Examined phases of burning:

- PHASE I: **FIRING**
  The ignition of the first batch in the cold fireplace was carried out from top down with 50 g of small wood chips.
- PHASE II: **COMBUSTION**
  After 35 min, the next batch was put in the wood combustion residues for self-ignition and burned for further 35 min, then the next batches were combusted for 50 min and 70 min.
- PHASE III: **AFTERBURNING**
  The last phase lasted for 50 min.

After each stage of burning the filter with PM was collected.

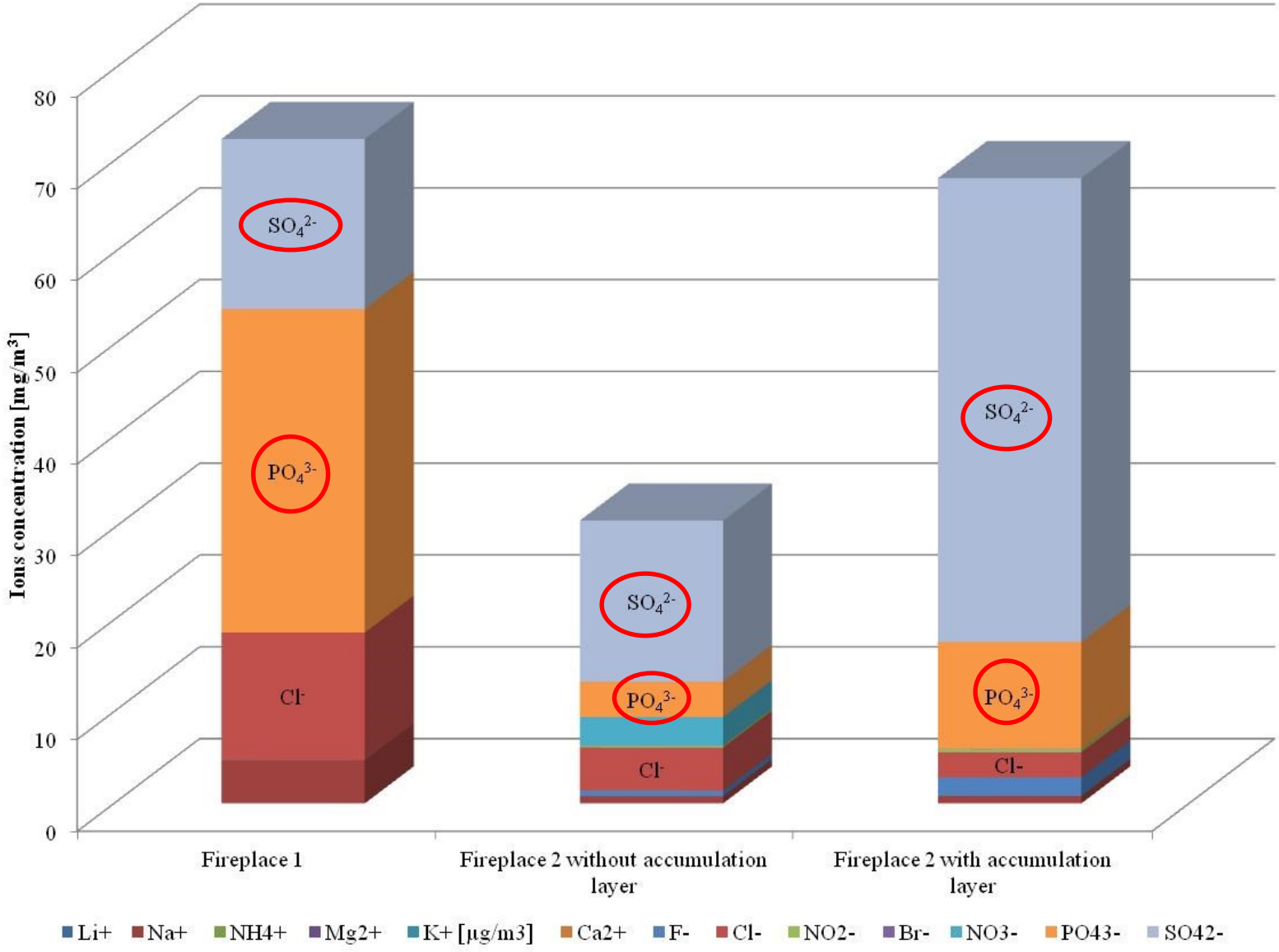
Results: Emitted pollutants

	Fireplace 1	Fireplace 2 without accumulation layer	Fireplace 2 with accumulation layer
PM [mg·kg^{-1}]	1.49	5.05	5.68
CO [ppm, 13% O_2]	4595.56	3128.01	3506.29
NO [ppm]	64.9	57.2	44.5
NO_x [ppm]	81.5	65.0	53.0
O_2 [%]	16.5	17.5	17.6
SO_2 [ppm]	40.1	27.4	18.6

The obtained results of particulate matter mass was calculated in the reference to 1 kg of a burned fuel.

Results: Inorganic ion content in particulate matter

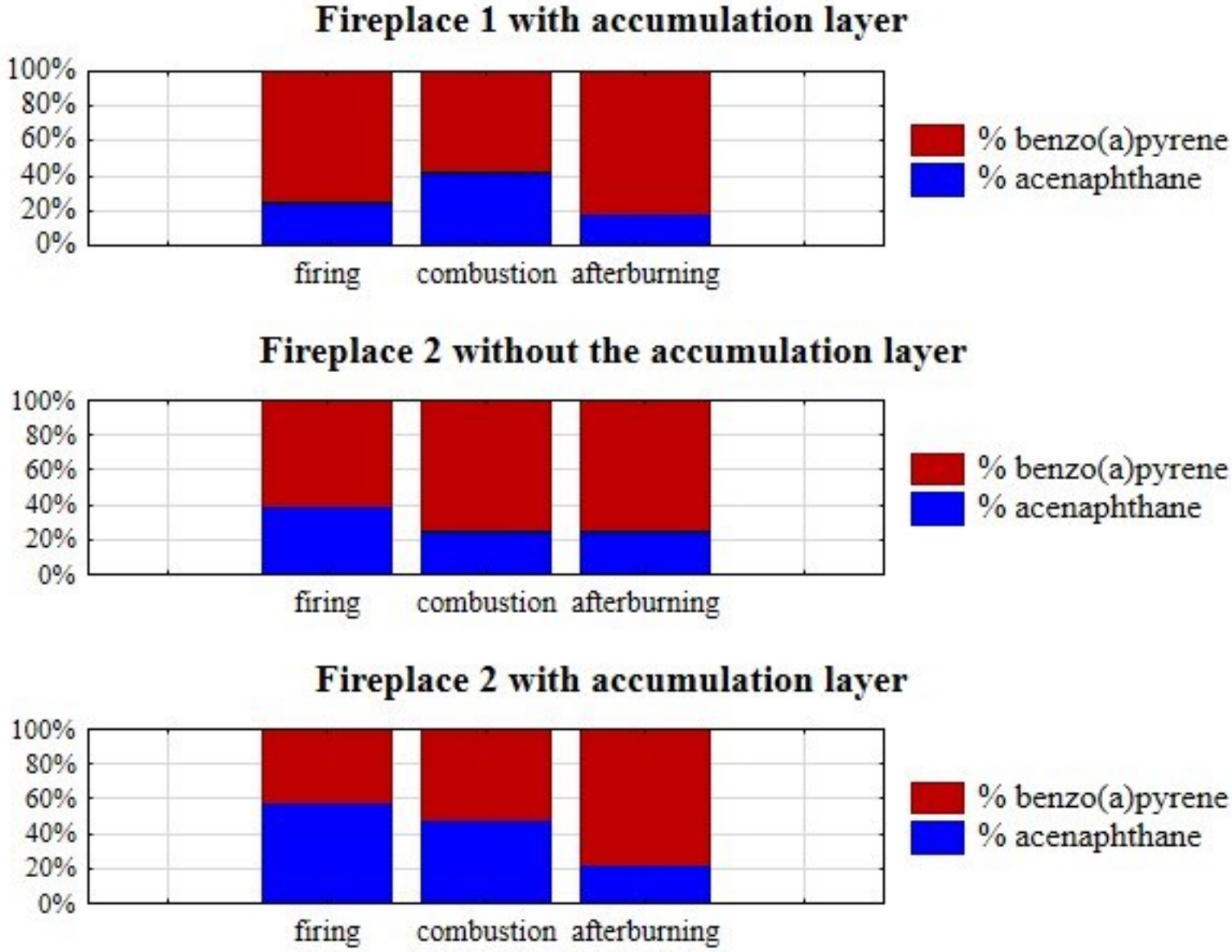
$$\frac{anions}{cations} = 13.3$$

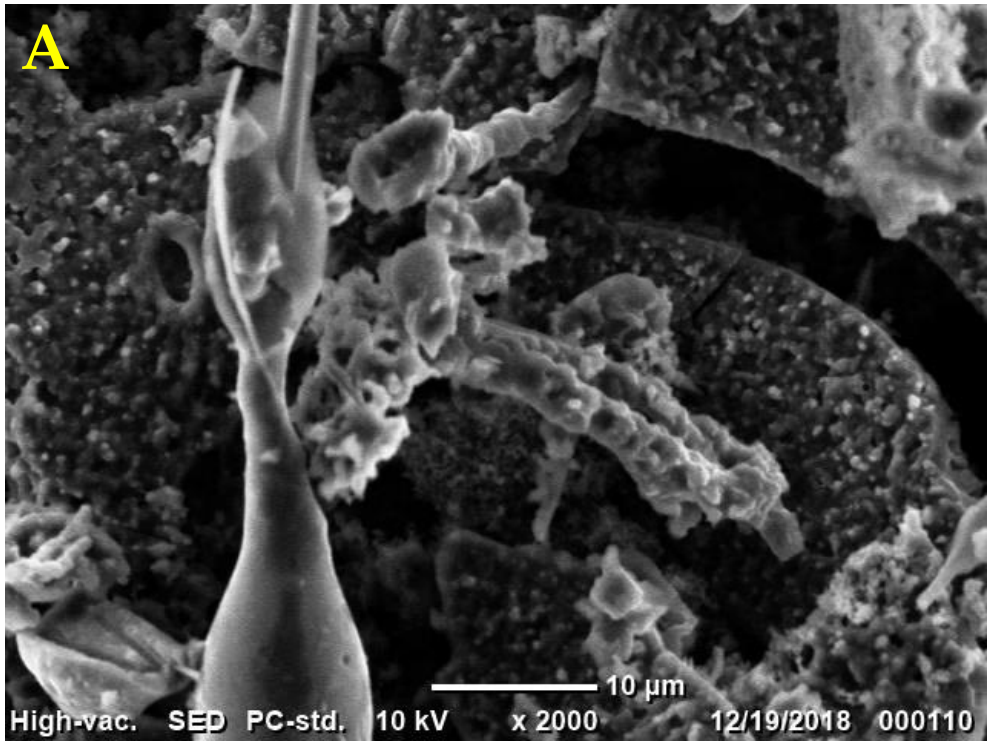


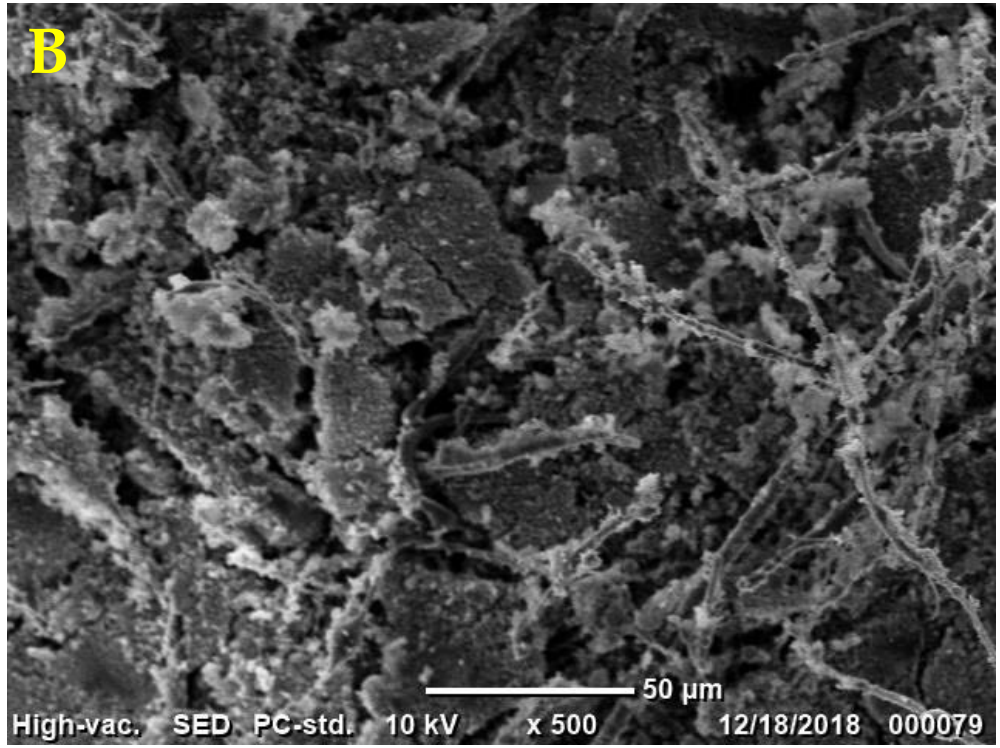
Results: Polycyclic aromatic hydrocarbons in particulate matter

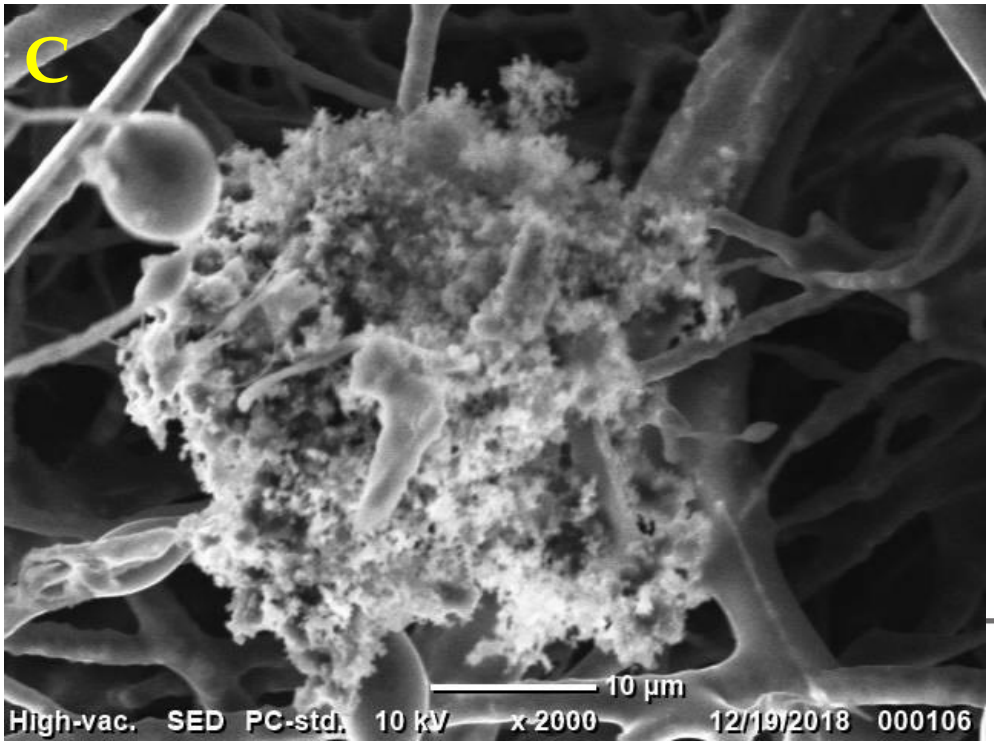
	Fireplace 1		Fireplace 2 without accumulation layer		Fireplace 2 with accumulation layer	
[mg·kg^{-1}]	BaP	PM	BaP	PM	BaP	PM
Firing	0.608	0.625	6.4	7.2	1.5	6.7
Combustion	0.6	1.5	3.2	4.6	6.5	6.6
Afterburning	1.0	6.8	5.7	7.8	2.0	4.2
PAHs mass	85 % of PM mass		74 % of PM mass		77 % of PM mass	

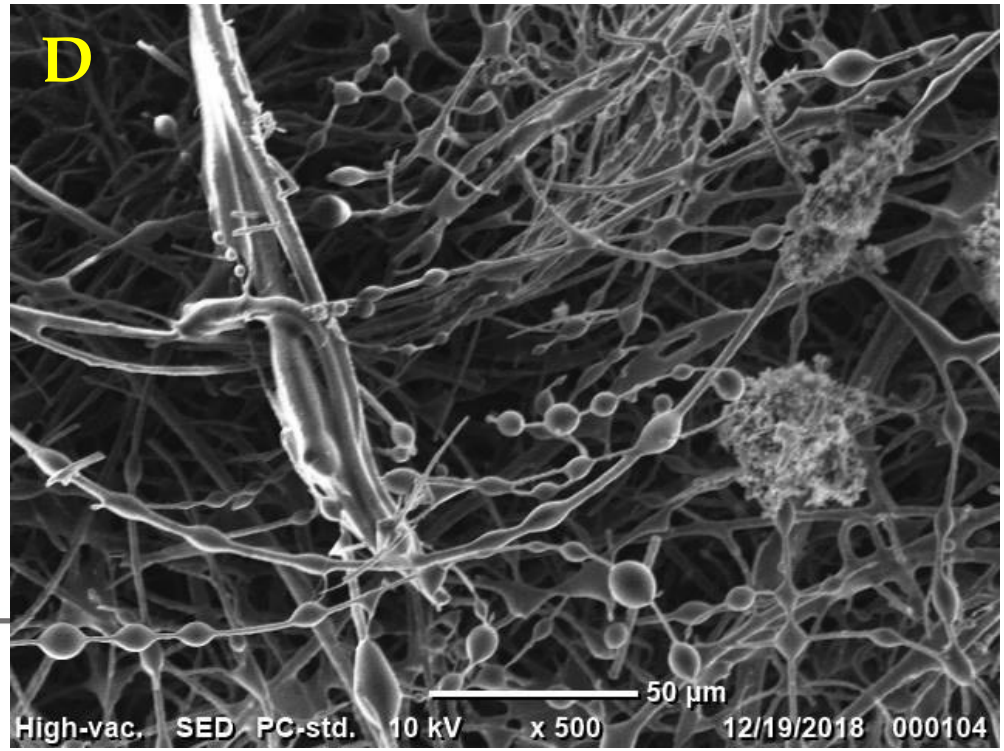
Results: Polycyclic aromatic hydrocarbons in particulate matter




A
10 µm
High-vac. SED PC-std. 10 kV x 2000 12/19/2018 000110

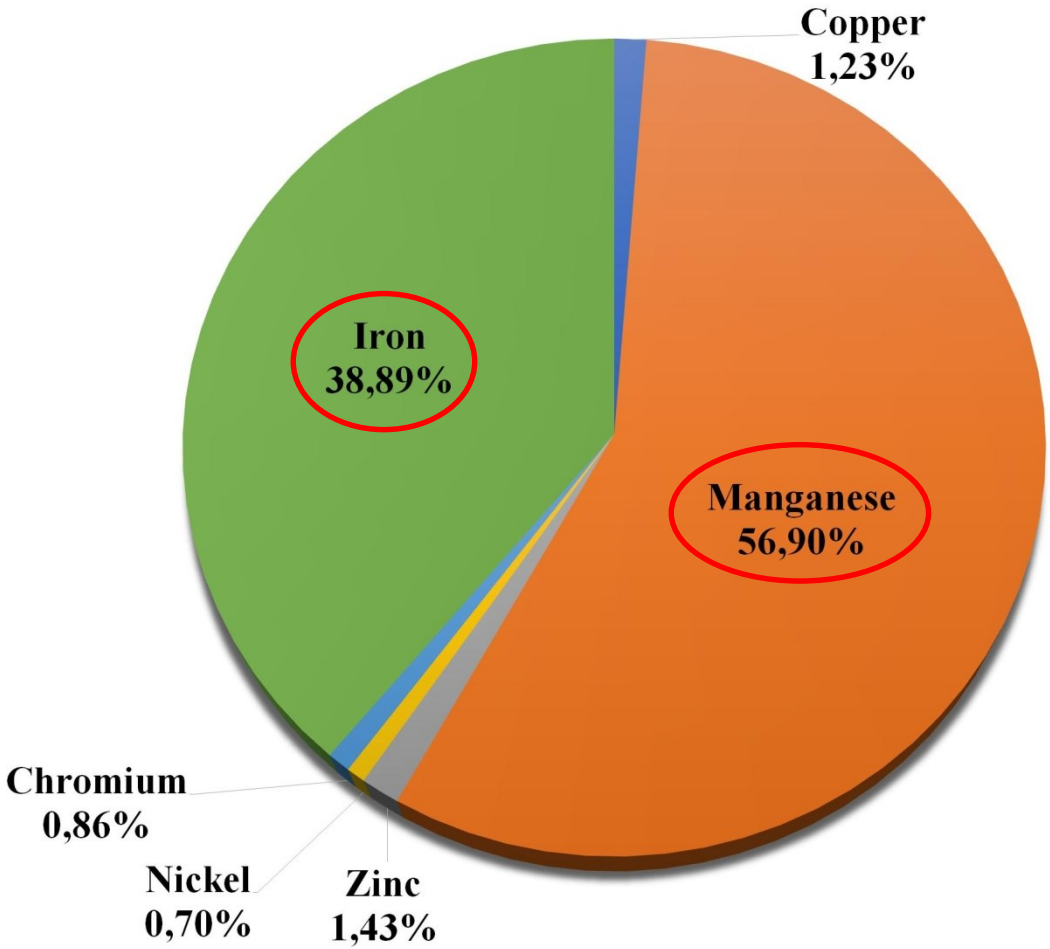

B
50 µm
High-vac. SED PC-std. 10 kV x 500 12/18/2018 000079


C
10 µm
High-vac. SED PC-std. 10 kV x 2000 12/19/2018 000106

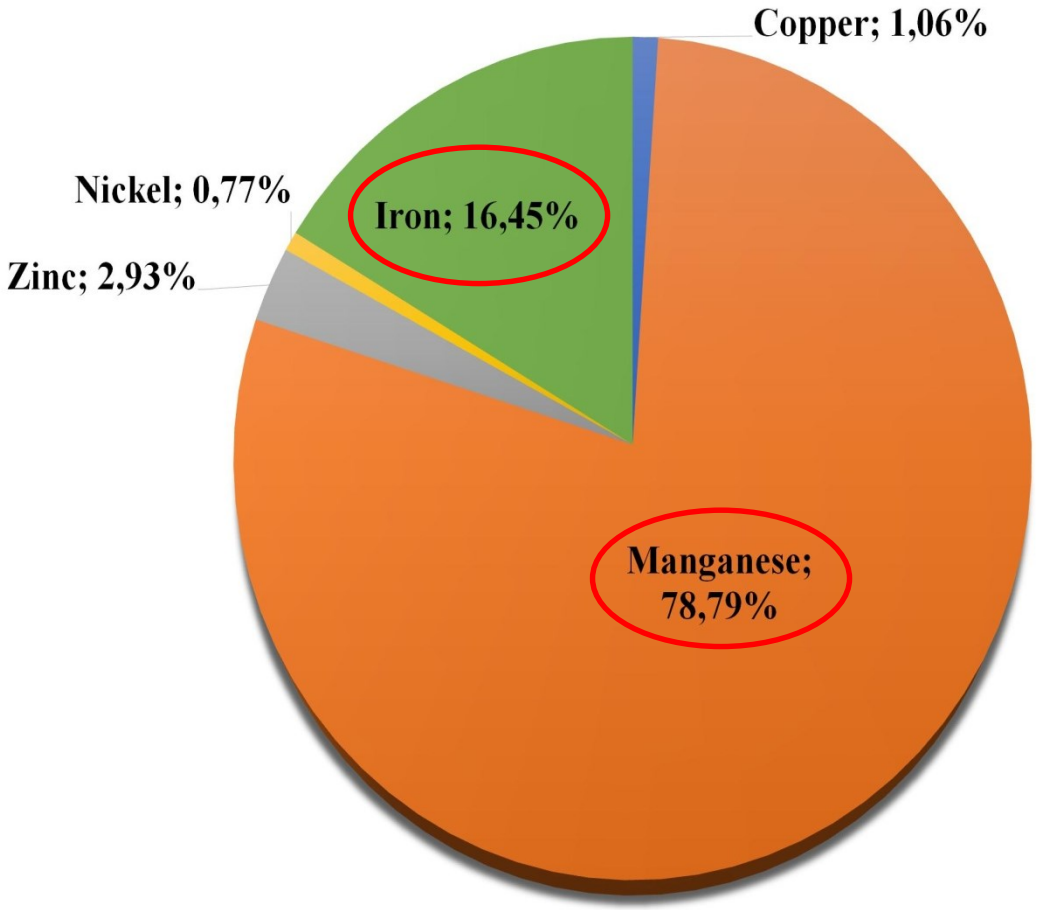

D
50 µm
High-vac. SED PC-std. 10 kV x 500 12/19/2018 000104

Results: The metal content in ashes

Metal content in ashes from combustion processes in Fireplace 1

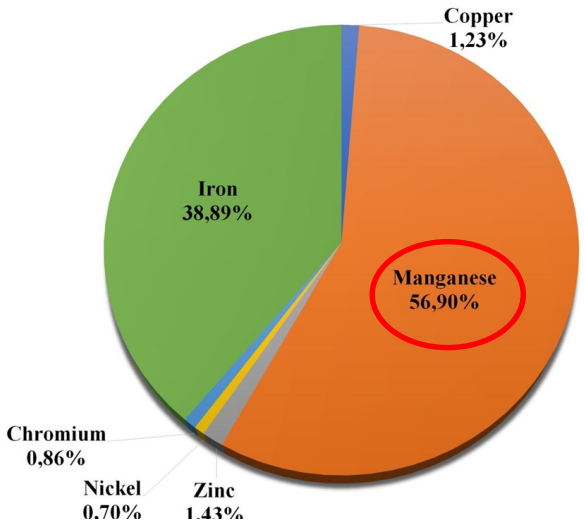


Metal content in ashes from combustion processes in Fireplace 2

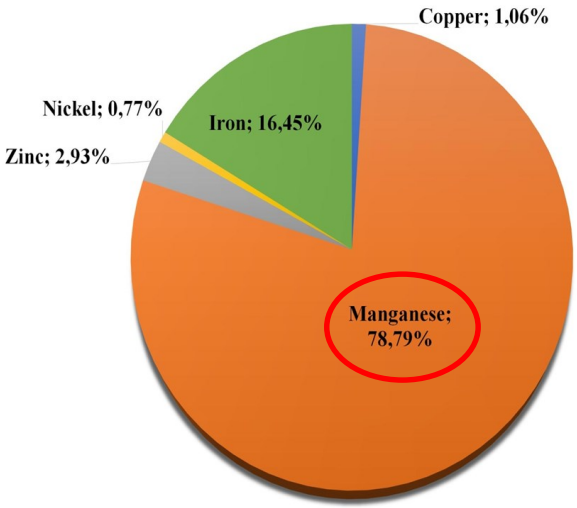


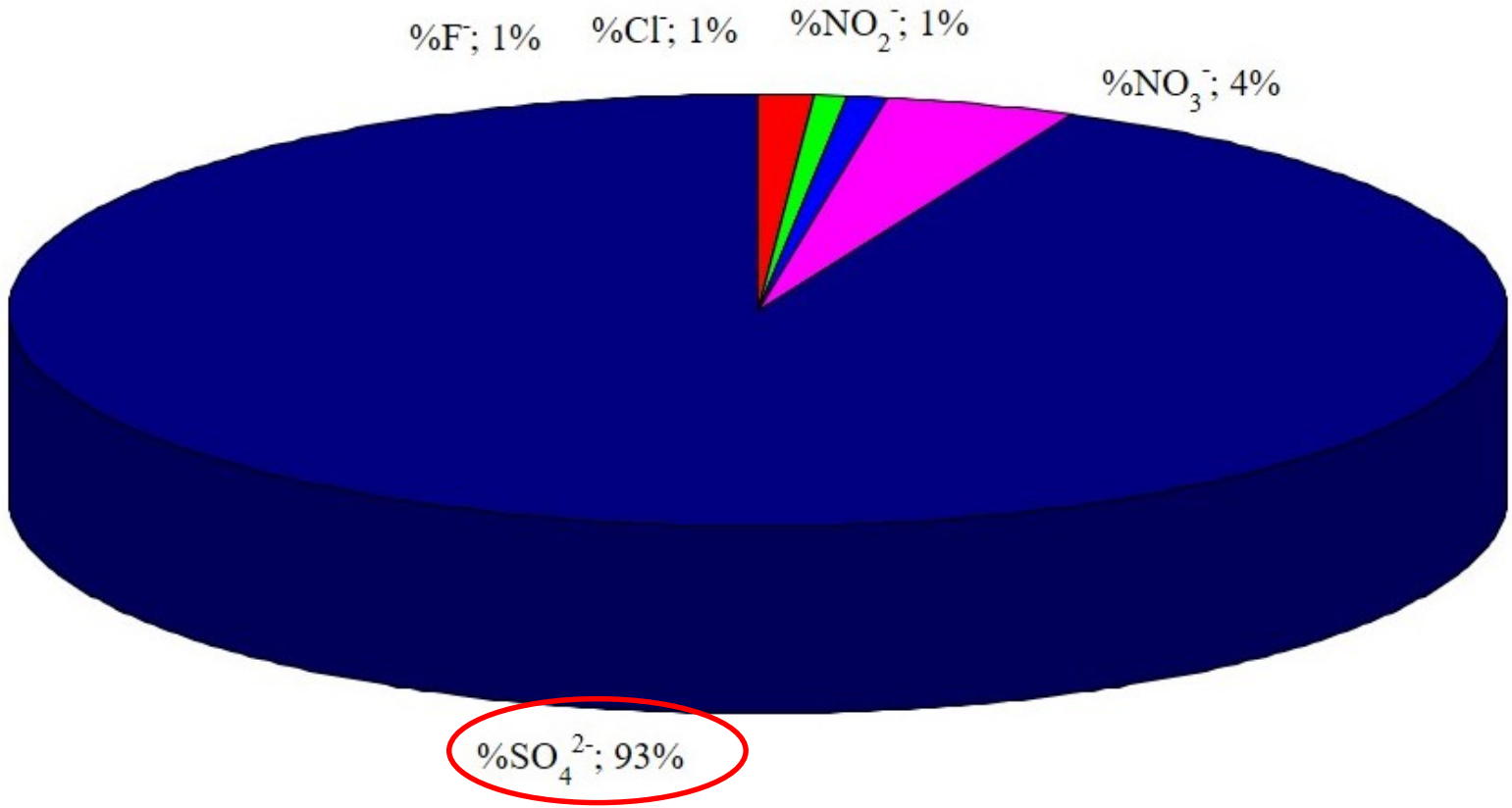
Results: Chemical composition of ashes

Metal content in ashes from combustion processes in Fireplace 1



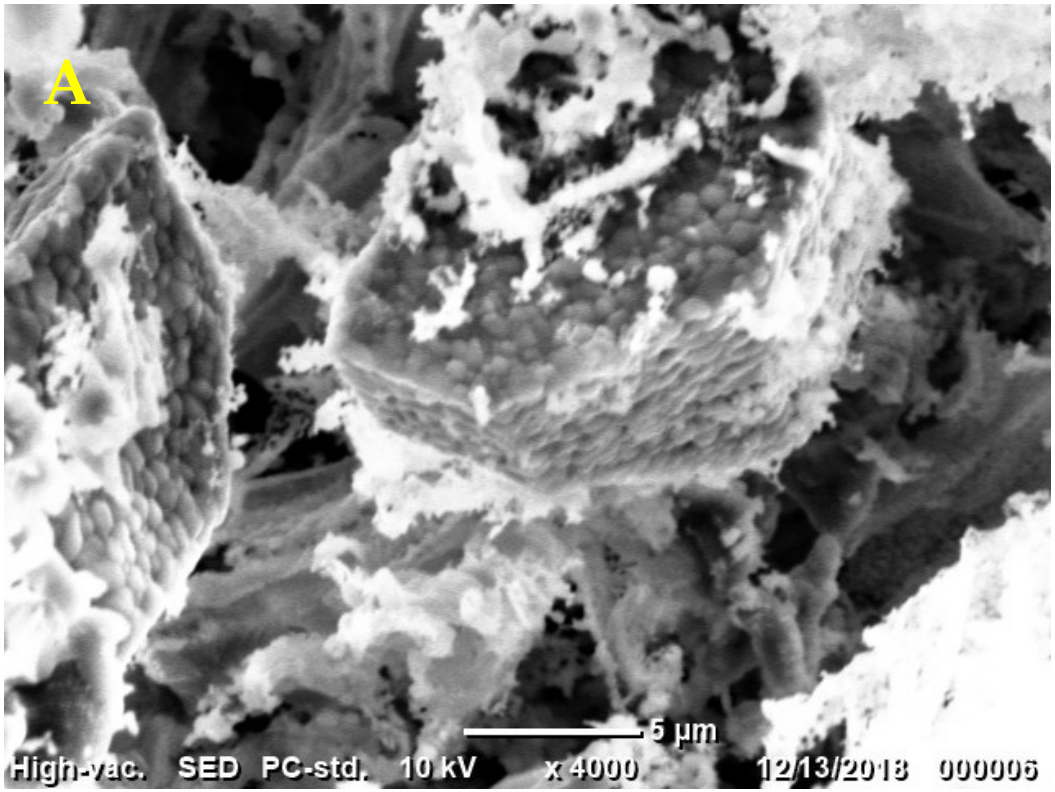
Metal content in ashes from combustion processes in Fireplace 2

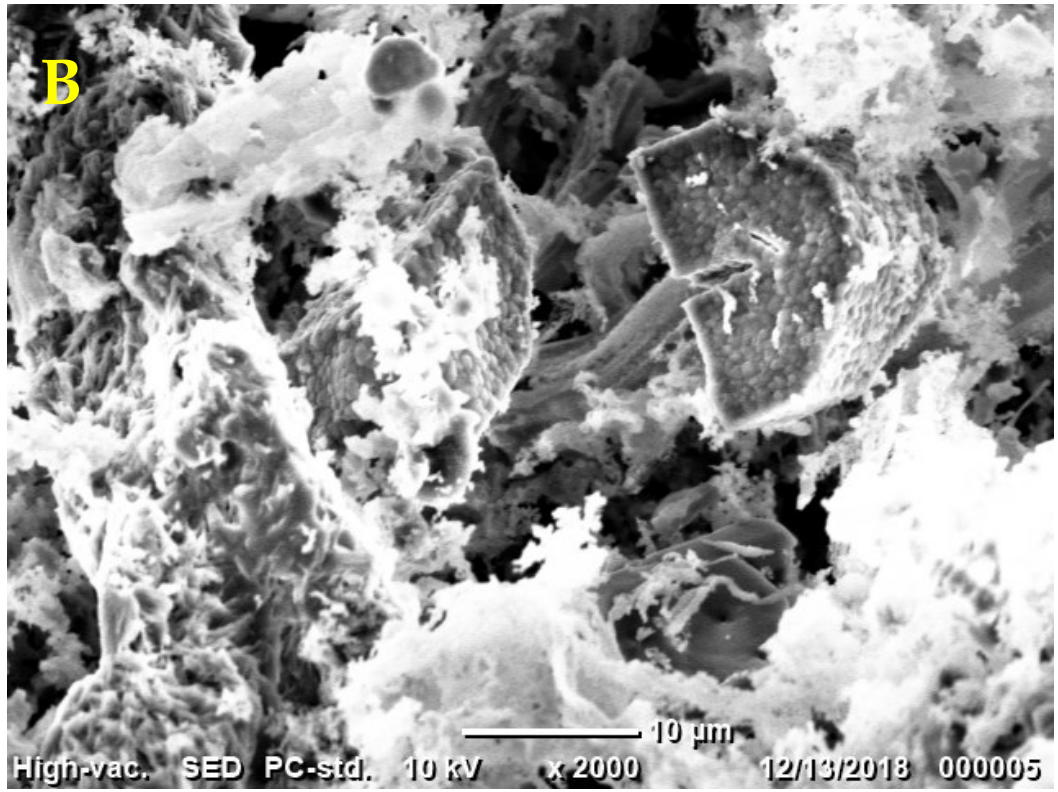




The average anion content in ashes

SEM analysis of ashes





Conclusions

- According to the SEM analysis the average diameter of collected solid particles was below 30 μm. The particles were a cluster of other particles with smaller diameters even of tens nanometers
- Among determined PAHs acenaphthene and benzo(a)pyrene exhibited the highest concentrations and accounted for almost 90% of all analysed PAHs
- The PAHs mass in total contributed to the significant mass of PM, which means that combustion generated PM is in greater part of organic origin.
- The anions-to-cations ratio was calculated and equalled to 13.30. This suggests the significant excess of anions in relation to cations. Comparing the information obtained from the analysis of metal content in ashes it was found, with a high probability, that the missing cations are Mn^{2+} and Fe^{2+}.
- The SEM images of ashes the average diameter of particles is of size 10 μm. The particles feature a polyhedron shape and seem to be a separated body beyond the rest of the ashes. On the surface of larger particles, additional small irregularities of irregular shapes were observed.

Acknowledgements

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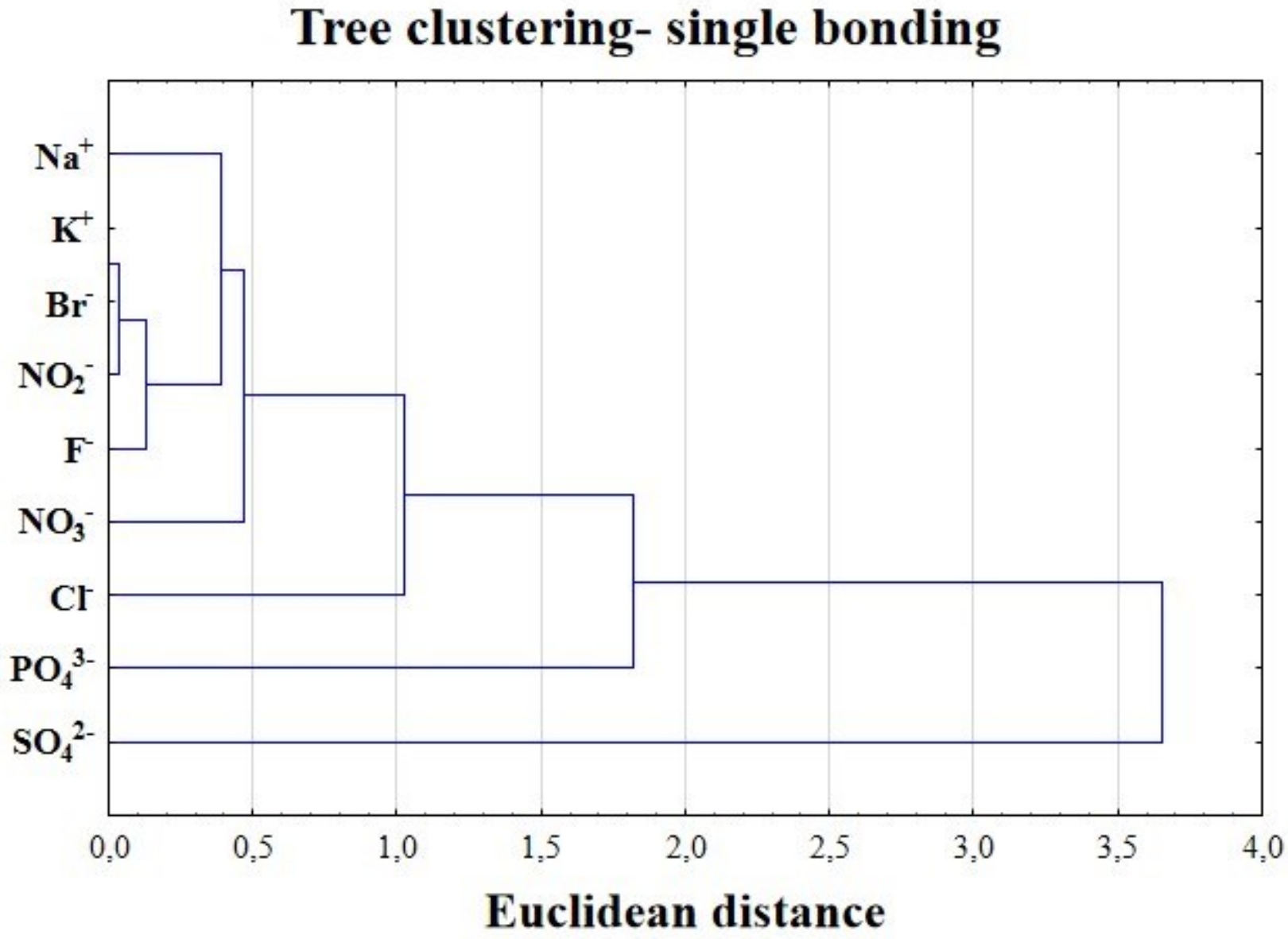
AGH

Thank You for Your attention!

Results: Inorganic ion content in particulate matter

Average content	Fireplace 1	Fireplace 2 without accumulation layer	Fireplace 2 with accumulation layer
Li^+ [µg/m^3]	0.61	0.04	0.025
Na^+ [mg/m^3]	4.7	0.78	0.82
NH_4^+ [µg/m^3]	0	0.21	0.12
Mg^{2+}[µg/m^3]	0.11	0.15	0.15
K^+ [µg/m^3]	19.14	14.75	9.86
Ca^{2+}[µg/m^3]	0.22	0.08	0.15
F^- [mg/m^3]	0.0024	0.60	2.02
Cl^- [mg/m^3]	13.88	4.70	2.74
NO_2^- [mg/m^3]	0	0.19	0.29
Br^- [µg/m^3]	0	0,22	0.59
NO_3^- [mg/m^3]	0	3.13	0.06
PO_4^{3-} [mg/m^3]	35.27	3.86	17.53
SO_4^{2-} [mg/m^3]	18.50	11.64	50.54

$$\frac{anions}{cations} = 13,30$$

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