Vpliv prometa, kurjenja lesa in industrije na sestavo in toksičnost delcev PM

K. Glojek[1,6], V. Dinh Ngoc Thuy[2], S. Weber[2], G. Uzu[2], M. Manousakas[3,4], R. Elazzouzi[2], K. Džepina[1], S. Darfeuil[2], P. Ginot[2], J.–L. Jaffrezo[2], R. Žabkar[5], J. Turšič[5], A. Podkoritnik[1] and **G. Močnik**[1]

1 Univerza v Novi Gorici, Center za raziskave atmosfere(CRA), Ajdovščina, 5270, Slovenia

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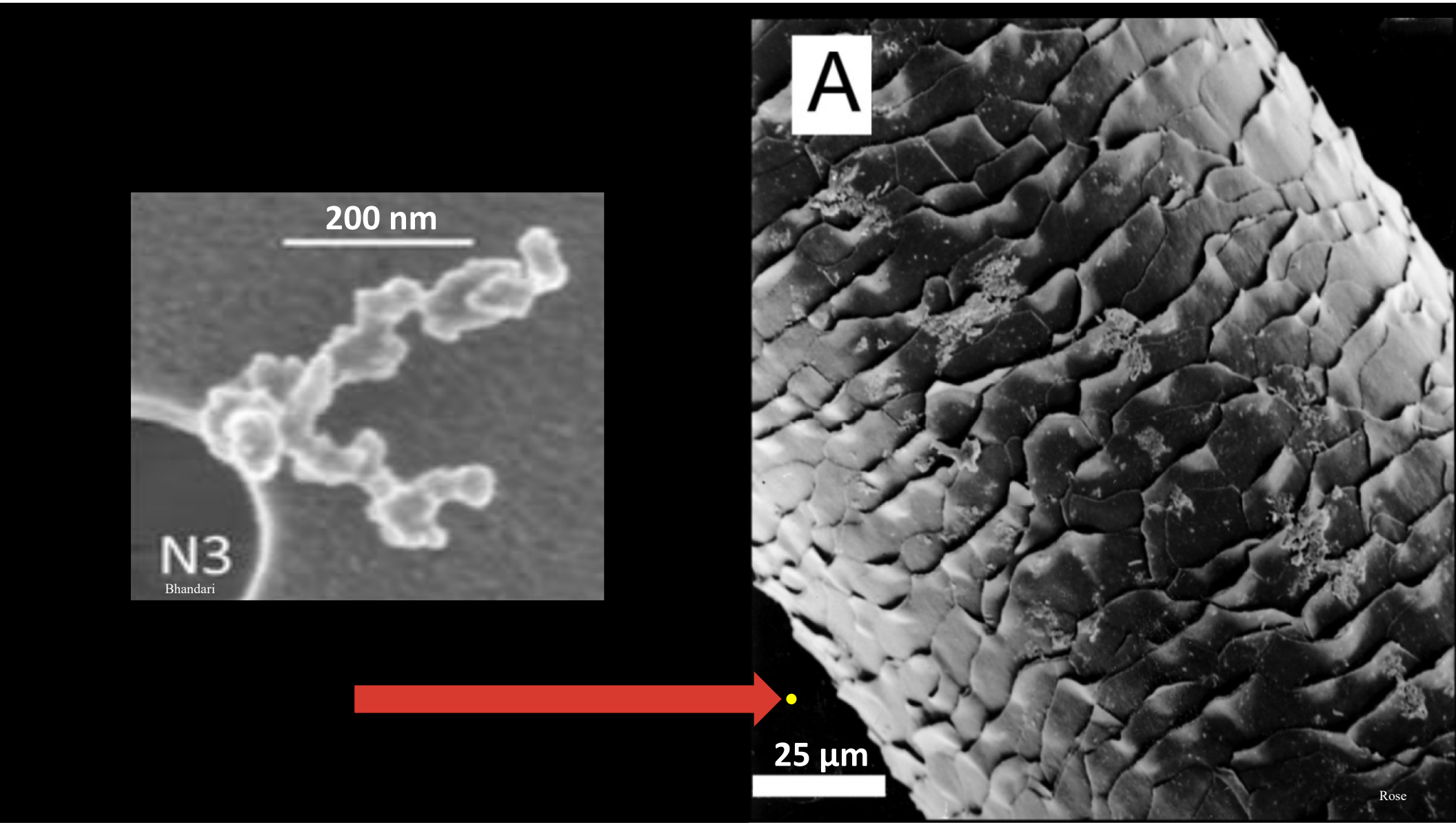
3 Paul Scherrer Institute (PSI), Laboratory of Atmospheric Chemistry, Villigen 5232, Switzerland

4 NCSR DEMOKRITOS Institute of Nuclear and Particle Physics, Agia Paraskevi, 15341, Greece

5 Slovenian Environment Agency, Ljubljana 1000, Slovenia

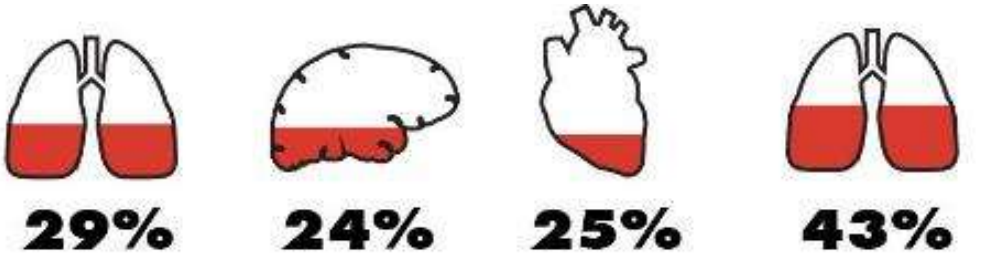
6 Institute of Environmental Assessment and Water Research (IDAEA-CSIC), Barcelona, 08034, Spain

Foto: Občina Kanal ob Soči


200 nm
N3
Bhandari
A
25 µm
Rose

Onesnažen zrak:

največja okoljska grožnja zdravju



29% SMRTI ZARADI **PLJUČNEGA RAKA**

24% SMRTI ZARADI **KAPI**

25% SMRTI ZARADI **SRČNIH BOLEZN**

43% SMRTI ZARADI **PLJUČNIH BOLEZNI**

Največji negativni učinki zaradi delcev. → Št. prezgodnjih smrti:

SVET **3,5> M**

EVROPA **240.000**

SLOVENIJA **1.300** → **13-krat > letno št. smrti v prometu**

Viri: EEA, 2021; WHO, 2020.

Official Journal
of the European Union

EN
L series

2024/2881

20.11.2024

DIRECTIVE (EU) 2024/2881 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 23 October 2024

on ambient air quality and cleaner air for Europe

(recast)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

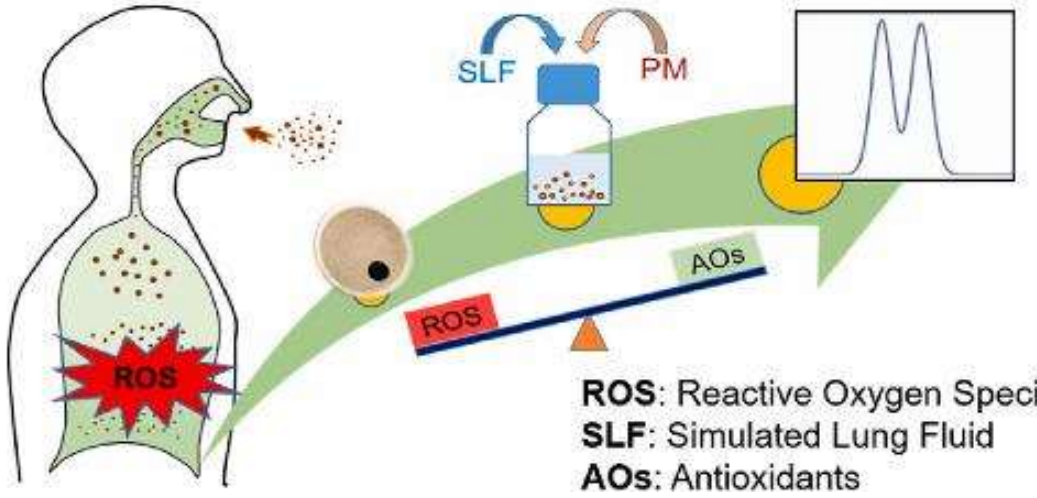
Table 3 – Pollutants recommended to be measured at monitoring supersites at urban background locations and rural background locations if not covered by the requirements of Tables 1 and 2

Pollutant	Type of measurement
Size distribution of UFP	Fixed or indicative measurements
Particulate matter oxidative potential	Fixed or indicative measurements

Merilo vpliva na zdravje: Oksidativni Potencial (OP)

PM delci kot povzročitelji oksidativnega stresa (Weber et al, 2021).

Kvantifikacija OP :



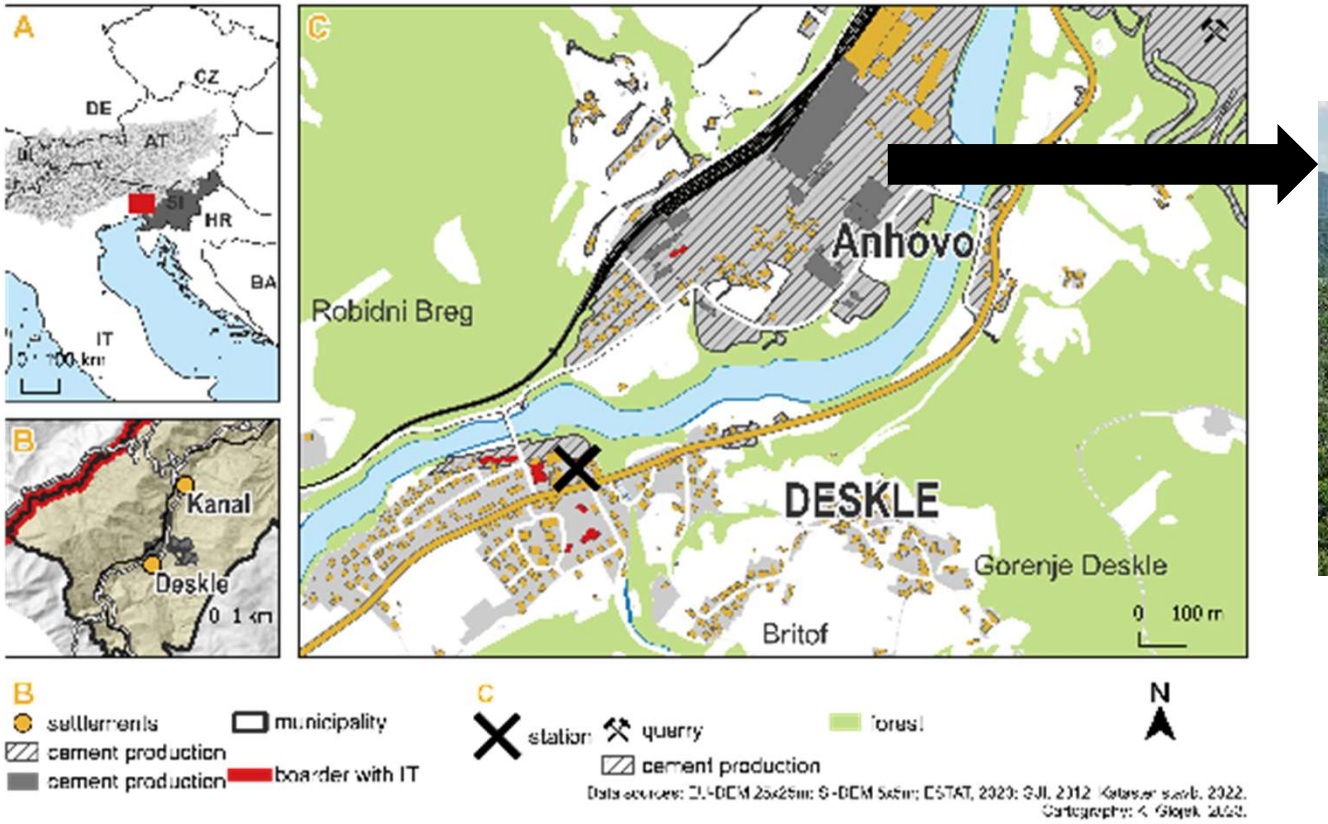
Absorbcijske meritve porabe oksidantov

Različna občutljivost na kemijske spojine in velikost PM.

- Dithiothreitol (**DDT**)
- Askorbinska kislina (**AA**)

Vir: Shahpoury et al., 2022.

Območje proučevanja: Kanal ob Soči



Meritve na strehi OŠ Deskle

zima 2020/21 pomlad 2021 poletje 2021 jesen 2021

PM_{10} & črni ogljik

PM_{10}

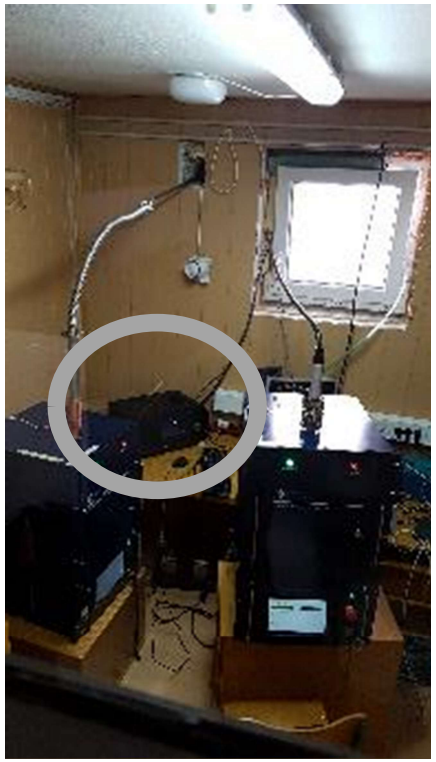
Digitel DHA-80

24-urni filtri

Črni ogljik

Aethalometer AE33:

1-min meritve



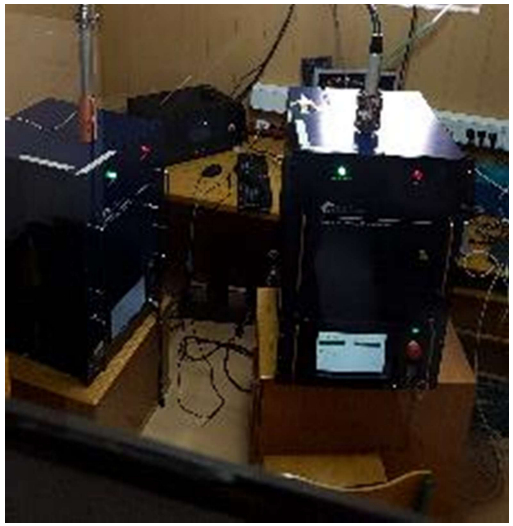
Merjeni parametri

parameter	metoda
organski ogljik	analiza OC/EC, EN 16909:2017 in Cavalli et al. (2010)
črni ogljik, BC	meritve z Aethalometrom, Drinovec (2015), Sandradewi (2008)
ioni in lahke organske spojine $NO3^-$, NO2-, $SO4^{2-}$, Cl^-, $NH4^+$, Na^+, K^+, Mg^{2+}, Ca^{2+}	ionska kromatografija IC-MS v PM10, drugače enako kot EN 16913:2017
glukonat, glikolat, propionat, format, MSA, propionat, piruvat, cis-pinonska kislina, 2-ketobutirična kisl., gliksolat, pinska kisl., butirat, 4-oksoheptanojska, glutarična, adipična, sksinična, malična kislina, tartarat, malonična, maleična kislina, oksalat, pinonat, azelaična, ftalična, vanilična kislina, 3-MBTCA, sebakična kisl., citrat	Chevrier (2016a), Chevrier et al., (2016b)
kovine Ag Al As Bi Cd Cs Cu Fe Mn Mo Ni Pb Rb Sb Sc Se Sn Ti V Zn	masni spektrometer z induktivno sklopljeno plazmo ICP-MS Chevrier (2016a), Chevrier et al., (2016b)
polioli in sladkorji oksalat, eritriol, ksilitol, arabitol, sorbitol, manitol, trealoza, levoglukozan, manozan, galaktozan, glukoza	tekočinska kromatografija visoke ločljivosti s pulzno amperometrično detekcijo HPLC-PAD Chevrier (2016a), Chevrier et al., (2016b)
oksidativni potencial	ditiotreitiol - DTT, askorbinska kislina - AA Weber et al. (2018) in reference tam

Določanje virov

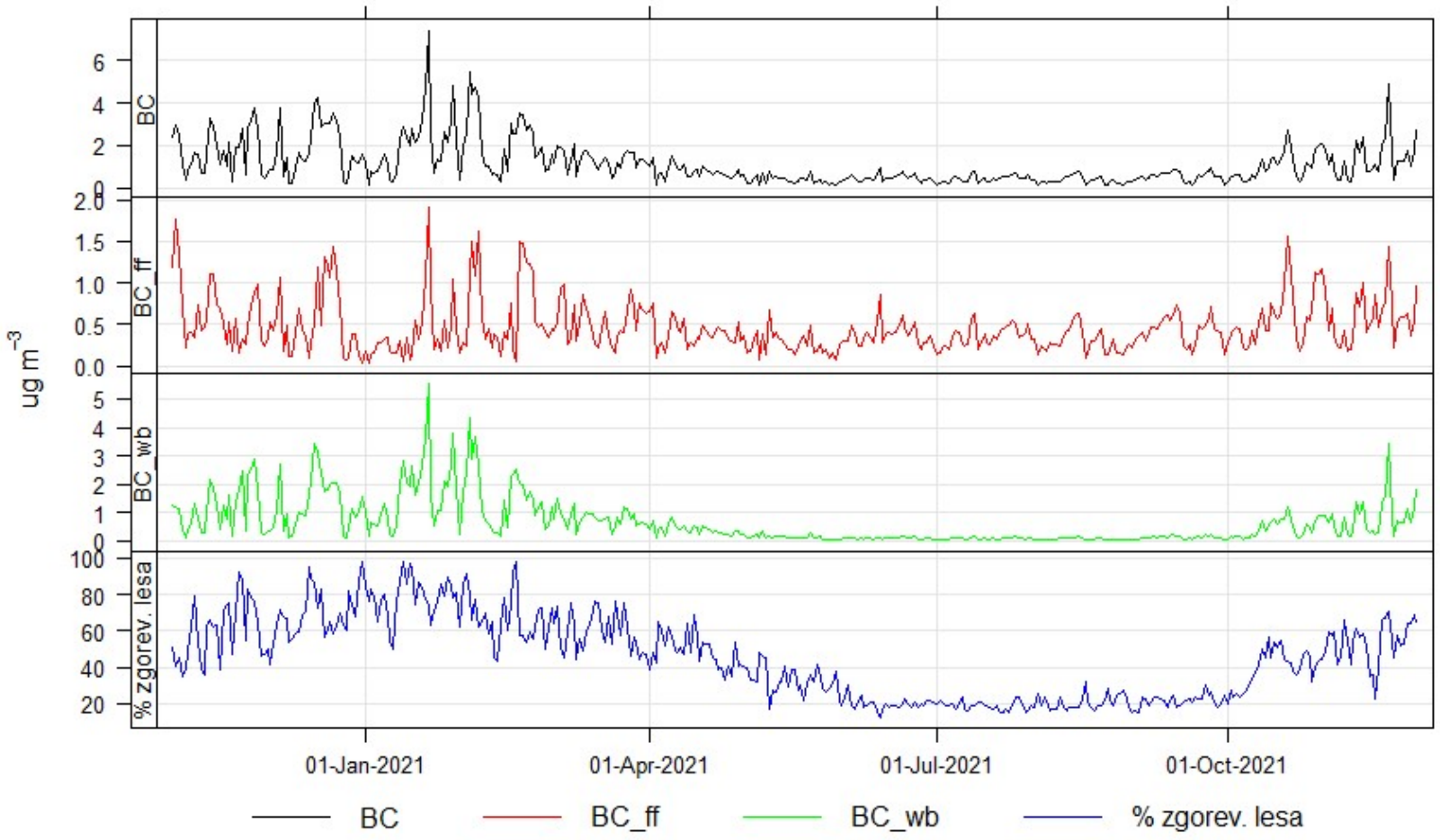
Kemijska sestava filtrov PM_{10}

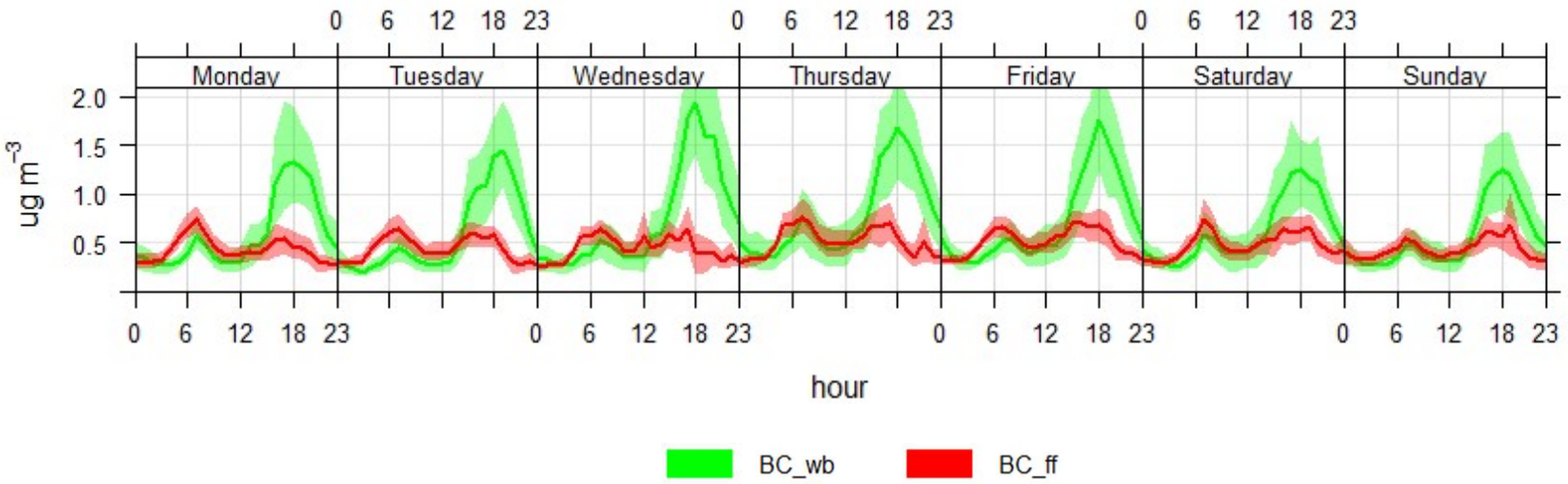
Črni ogljik

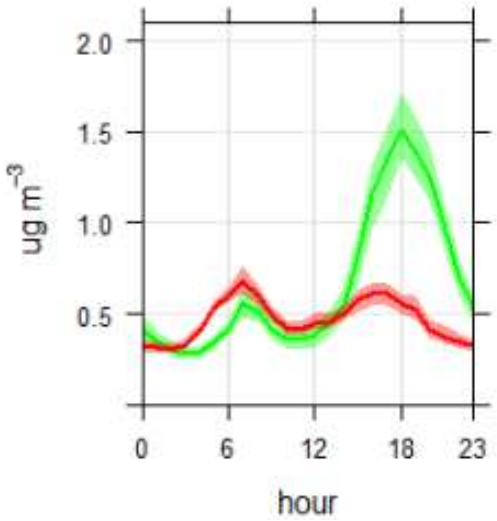


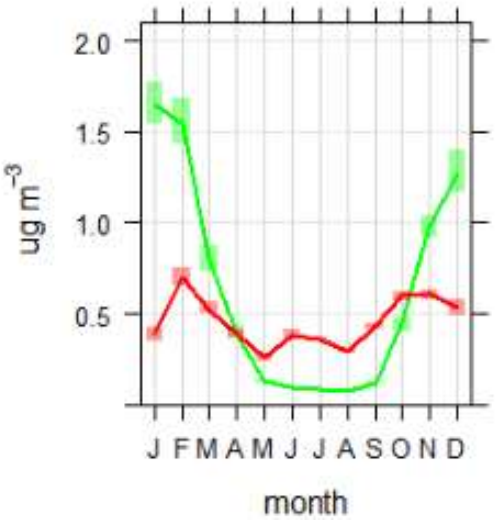
Pozitivna Matrična Faktorizacija (PMF)

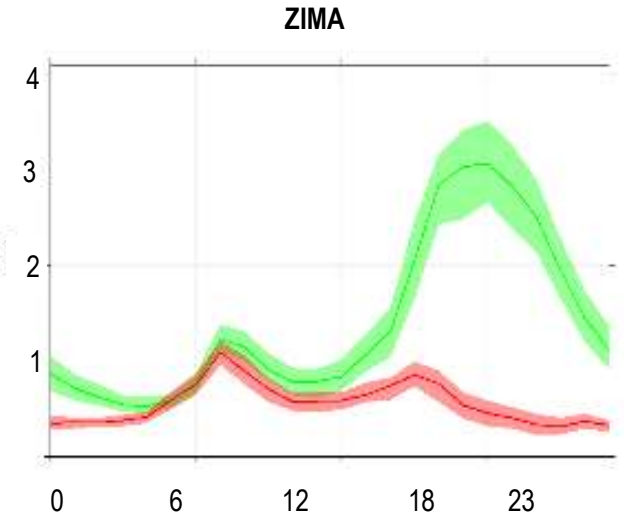
Viri črnega ogljika



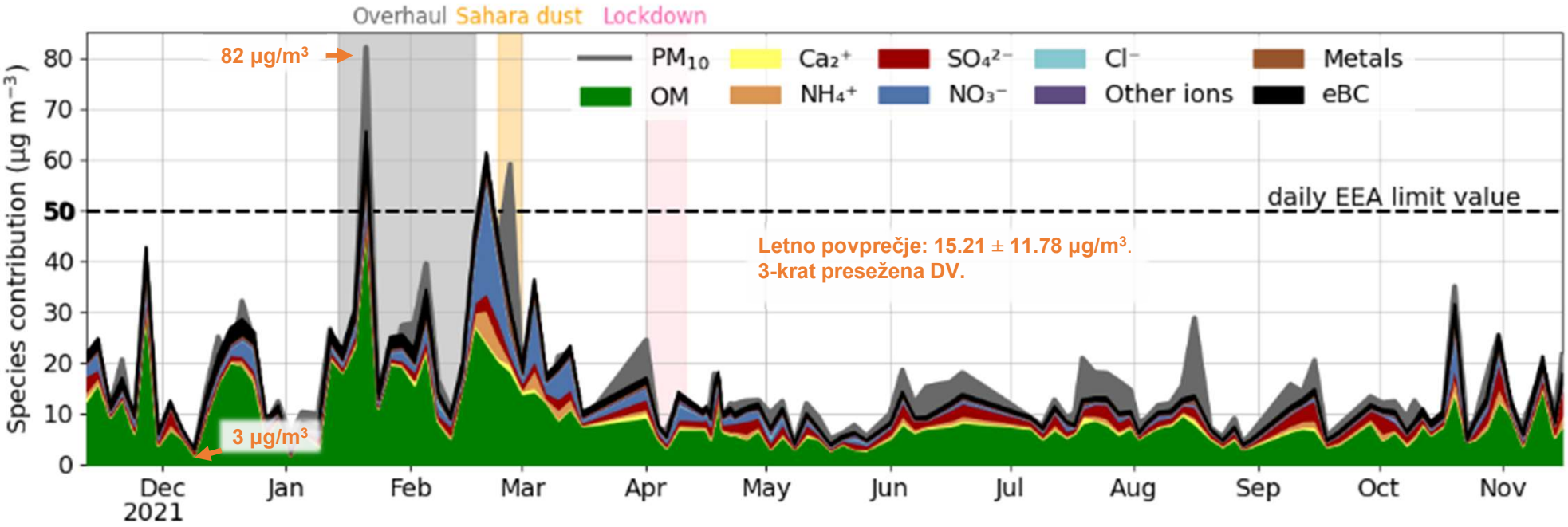

Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
ug m-3
hour
BC_wb
BC_ff


ug m-3
hour

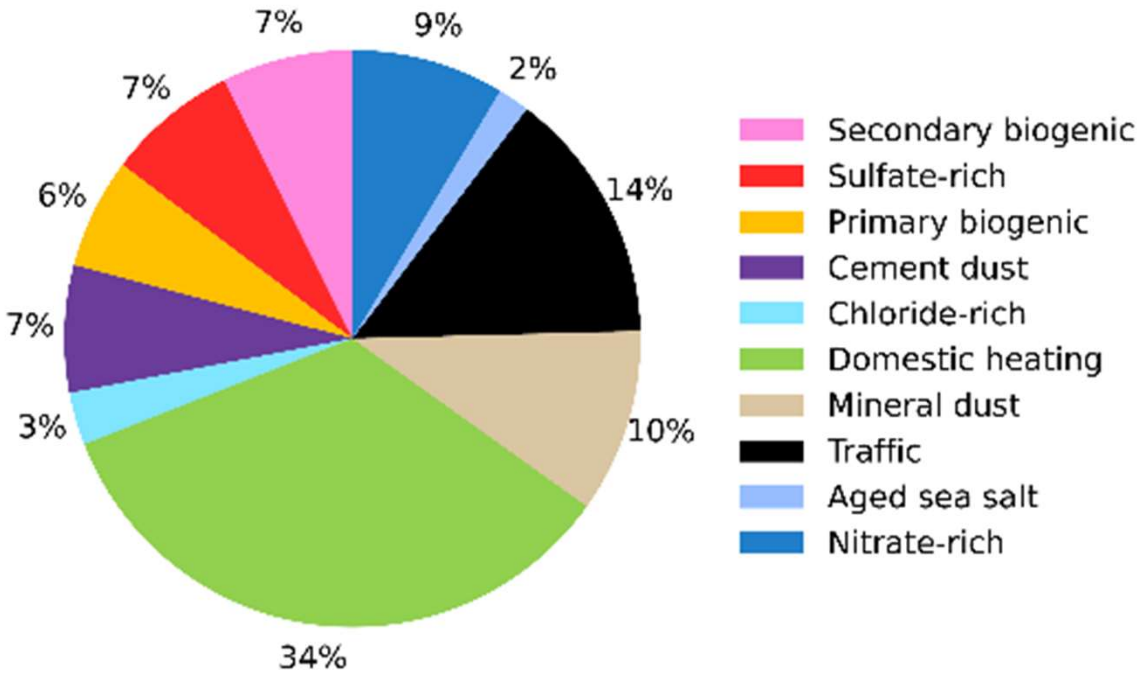

ug m-3
J F M A M J J A S O N D
month


ZIMA

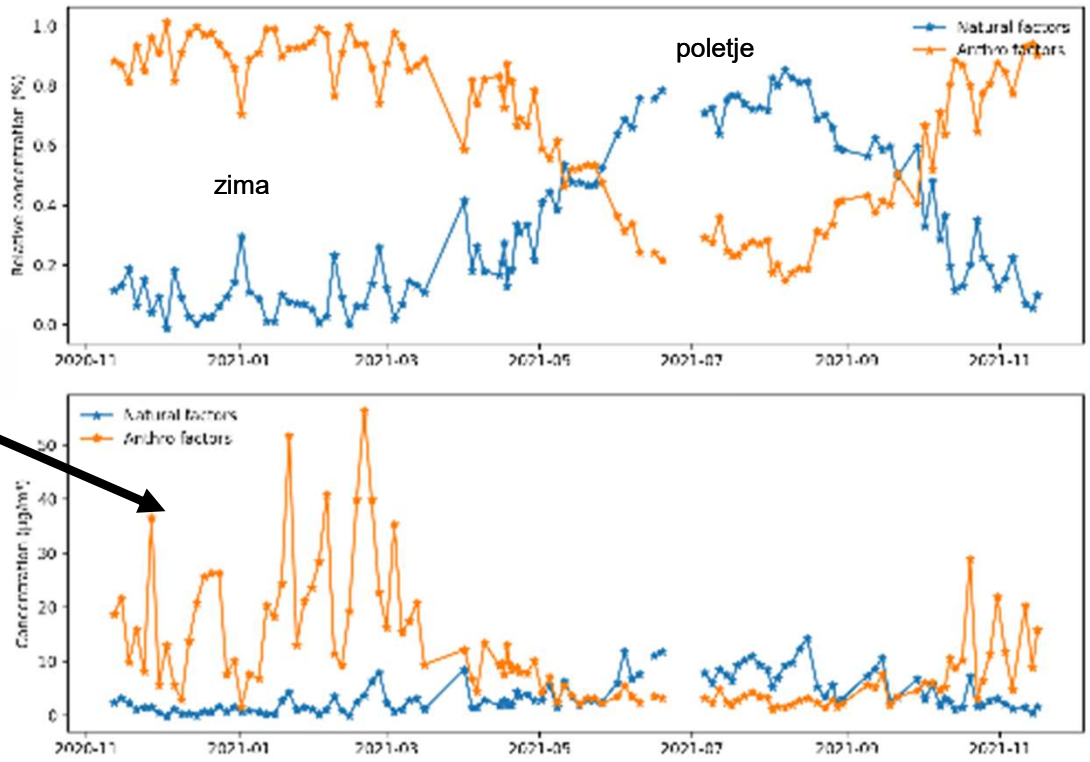
PM_{10} in kemijska sestava



PMF: viri PM_{10}



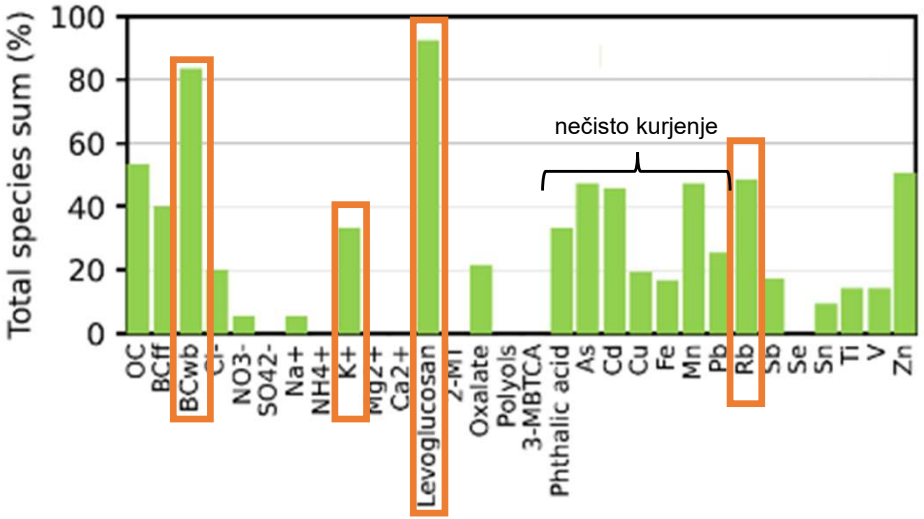
Naravni proti antropogeni viri



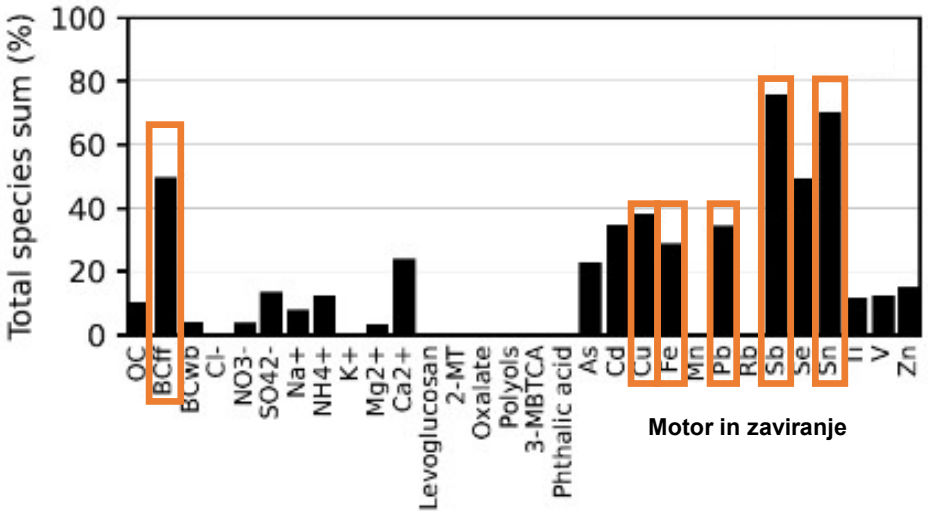
Antropogeni > > naravni.

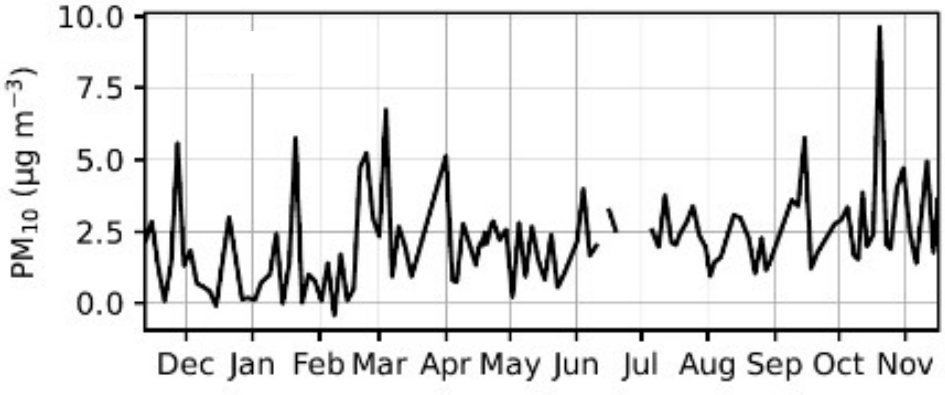
Antropogeni viri

Zgorevanje biomase



Promet



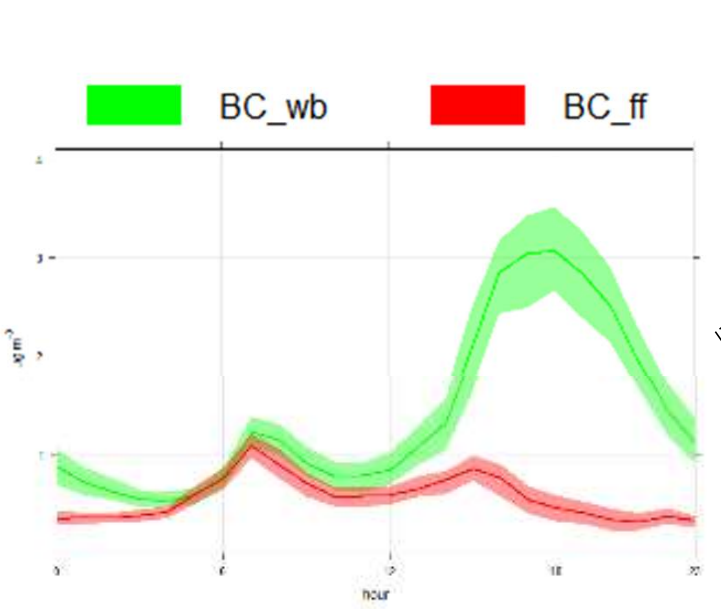


47%

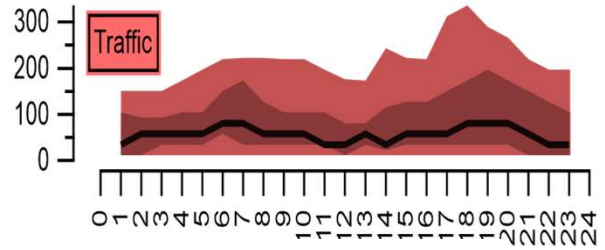
v industrijsko cono Anhovo

85%

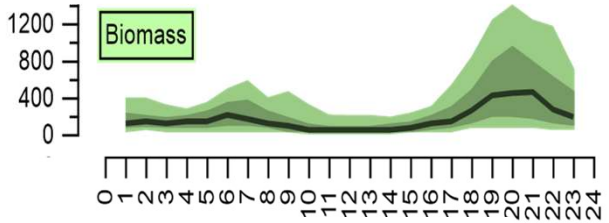
Zgorevanje biomase & Promet



Kovine v sledovih

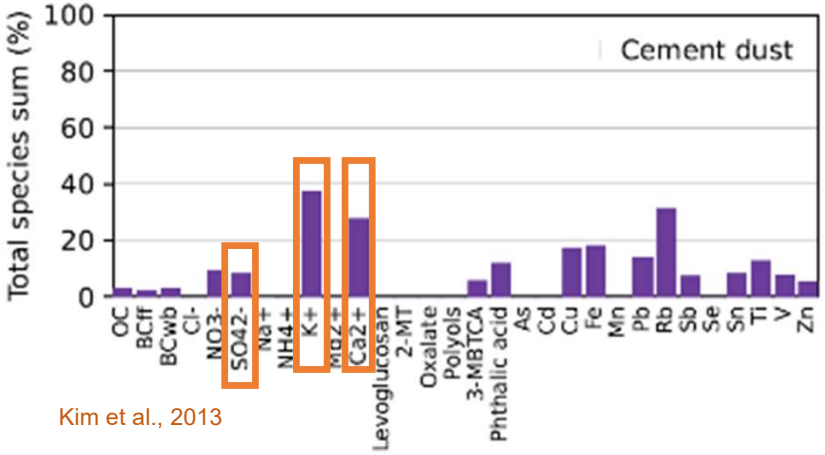


ura v dnevu

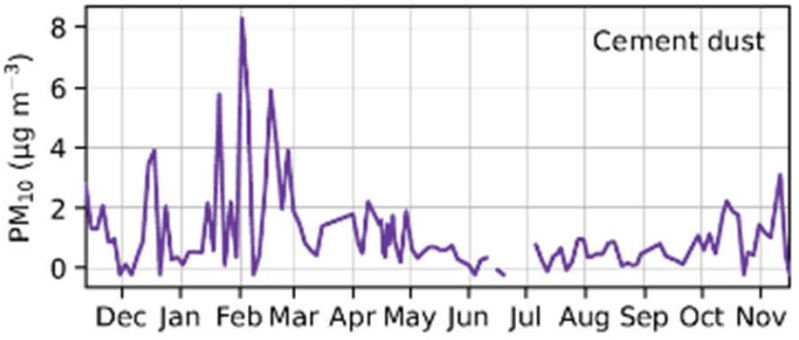


ura v dnevu

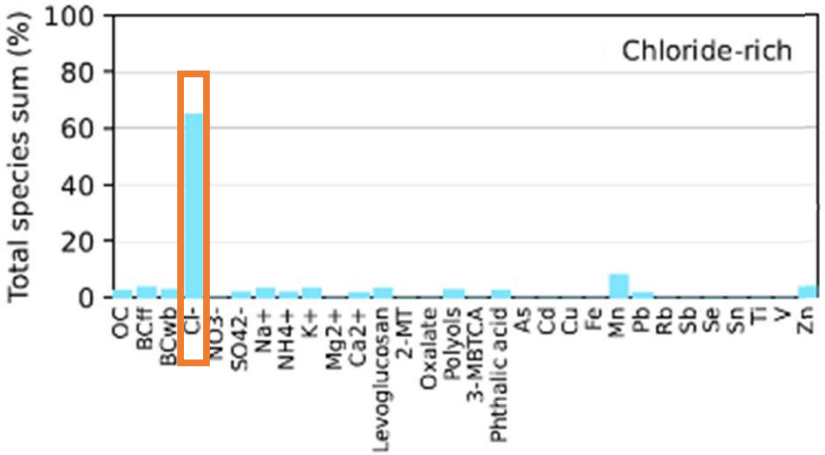
Industrijska vira

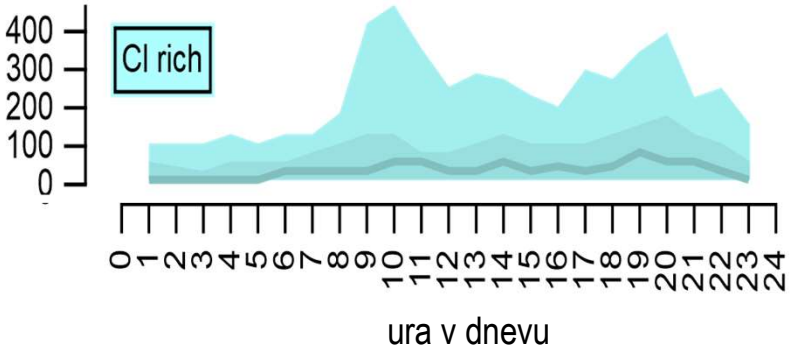


Kim et al., 2013

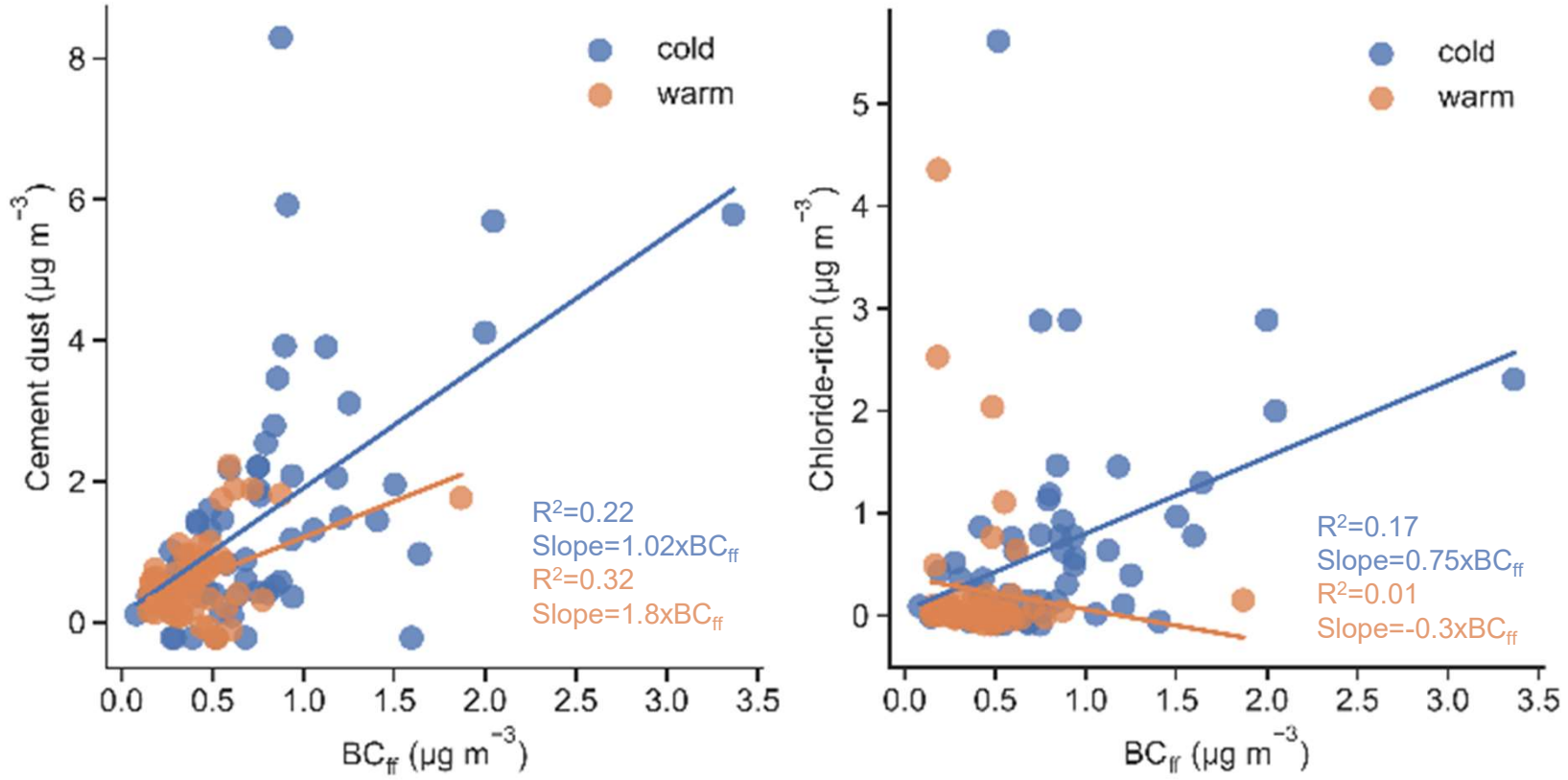


Kim et al., 2013

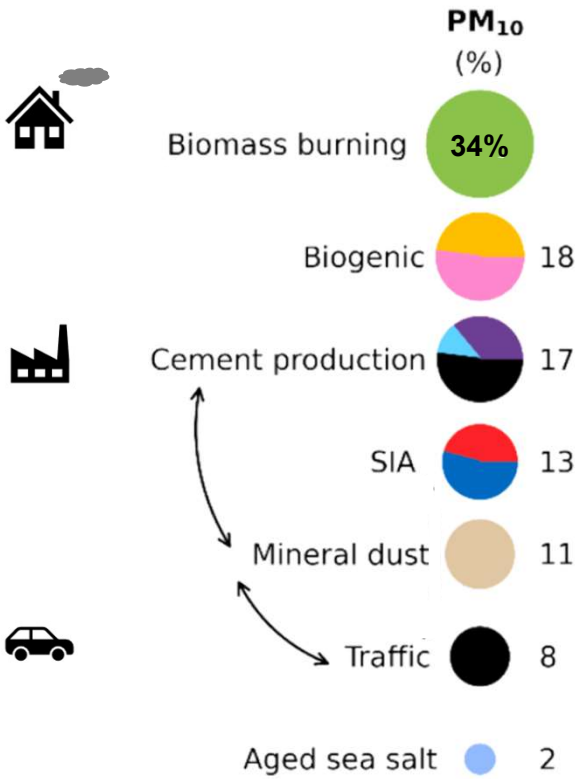


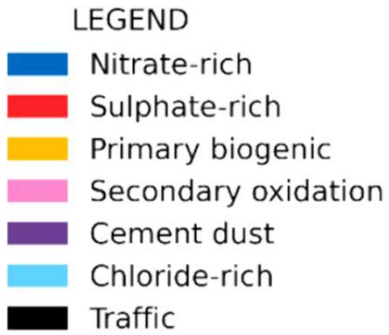


Vir: mehanski procesi

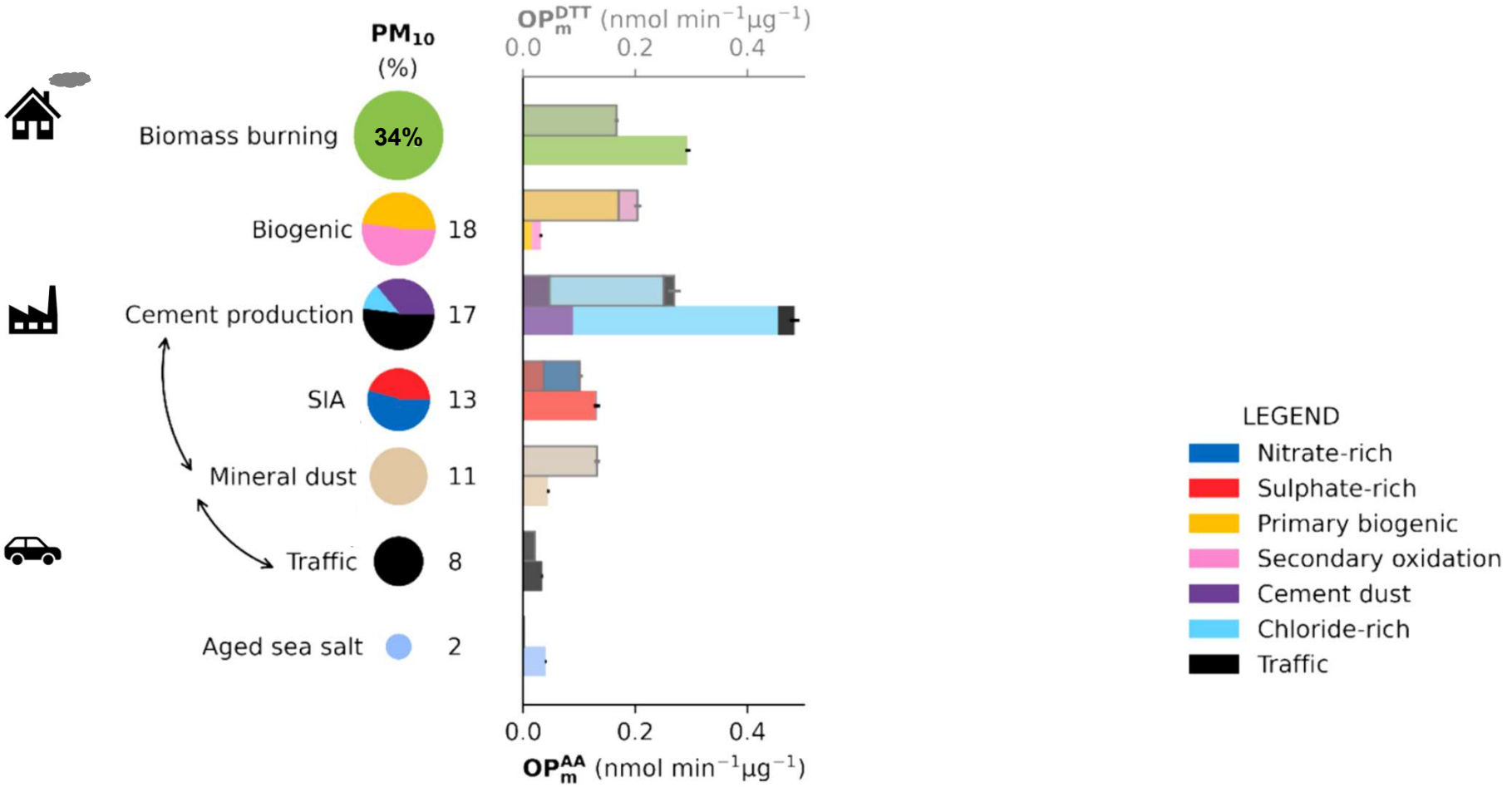


Skupni prispevek virov k PM_{10}

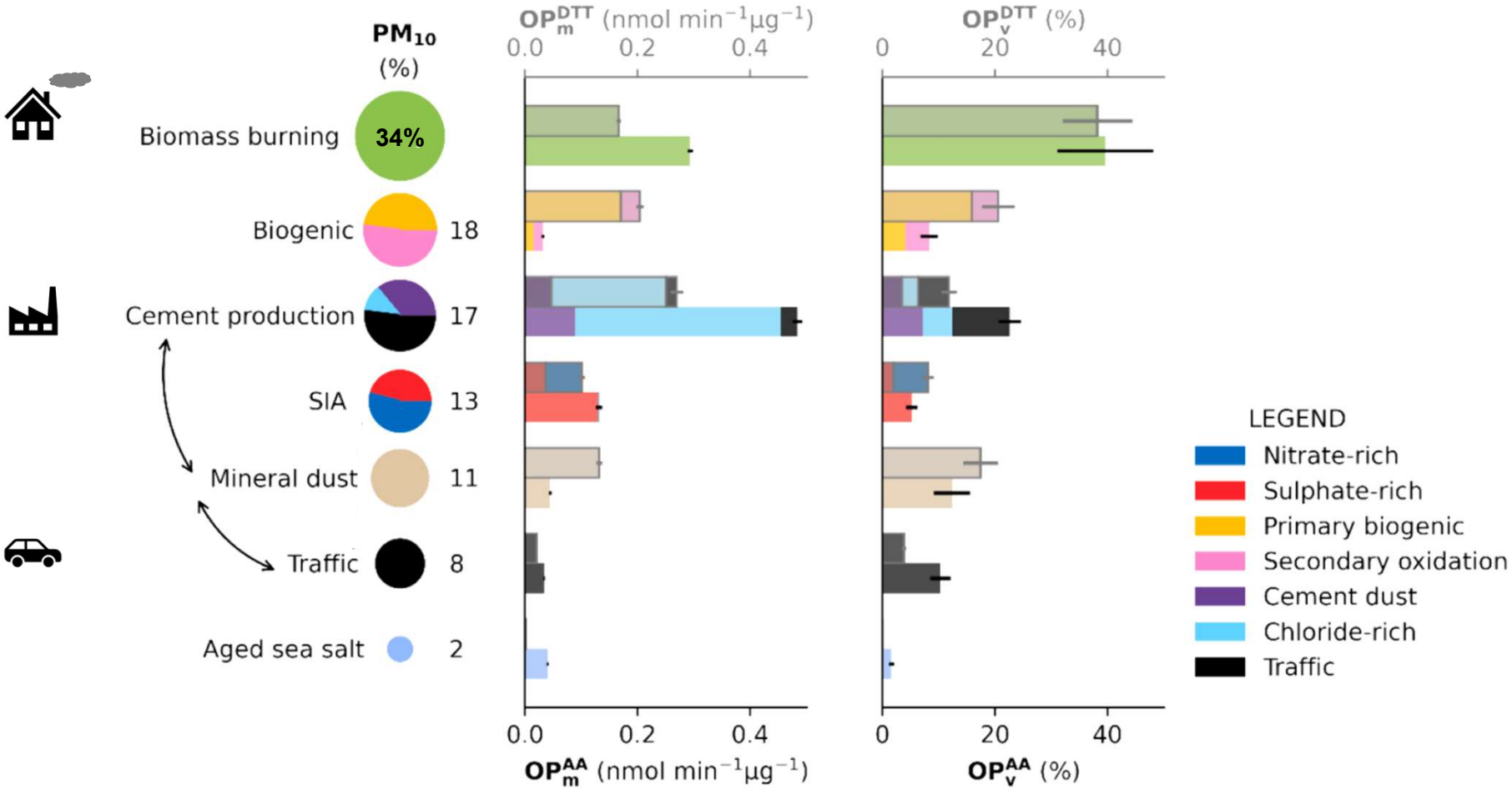




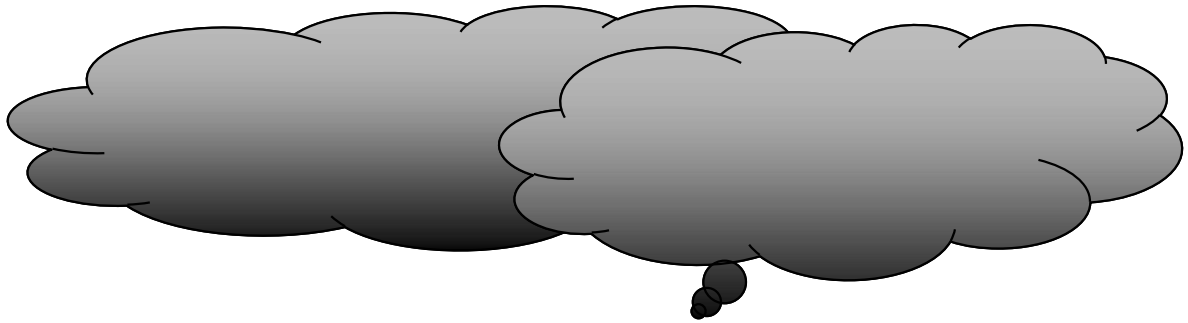
Skupni prispevek virov k OP_m



Skupni prispevek virov k OP_V



Povzetek



- **PM_{10} ≈ druga alpska območja.** (Herich et al., 2014)
- Najpomembnejši viri: 
- **OP ≈ med najvišjimi v Evropi.** (Daellenbach et al., 2020; Weber et al., 2021; Borlaza et al., 2021b)
- Nenavaden vir bogat **s kloridi,** z **visokim OP_m**. 
- Nadaljne raziskave:
  - primerjava rezultatov z drugimi uporabljenimi metodami;
  - vzorčenje resuspendiranega prahu na različnih lokacijah po dolini.

Hvala!

OBČINA KANAL OB SOČI

IGE

Institut des Géosciences de l'Environnement

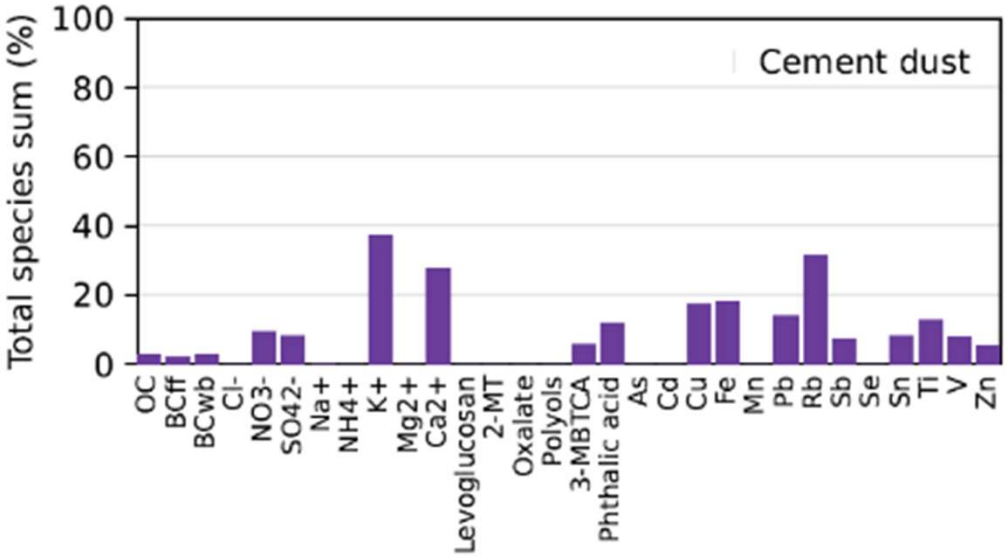
PSI

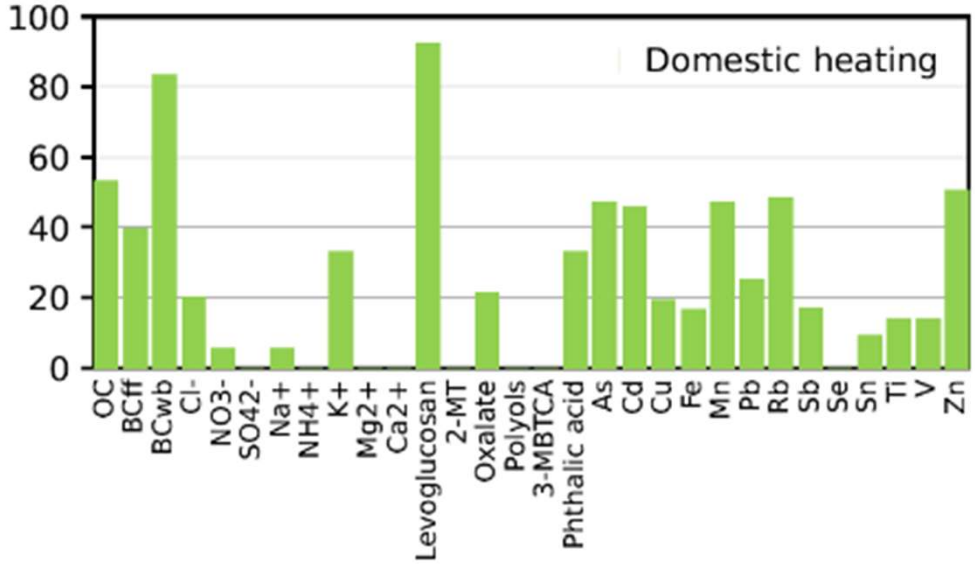
HAZE INSTRUMENTS

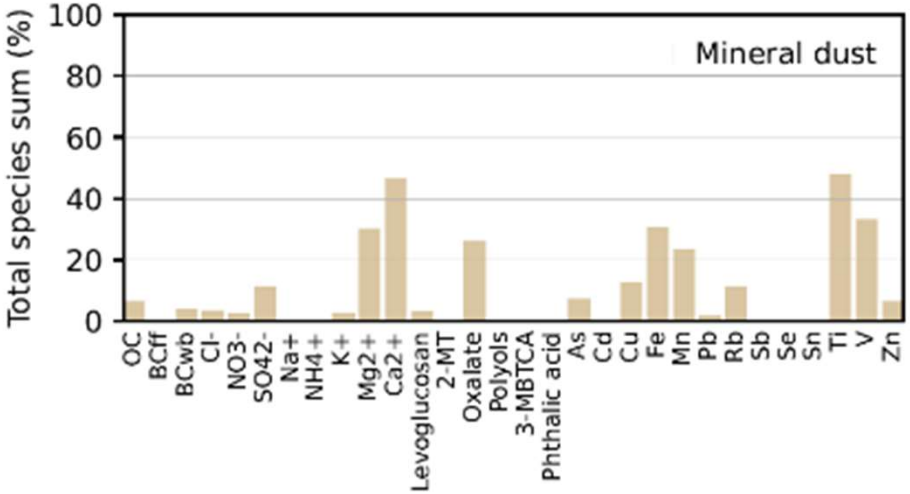
REPUBLIKA SLOVENIJA
MINISTRSTVO ZA OKOLJE IN PROSTOR
AGENCIJA REPUBLIKE SLOVENIJE ZA OKOLJE

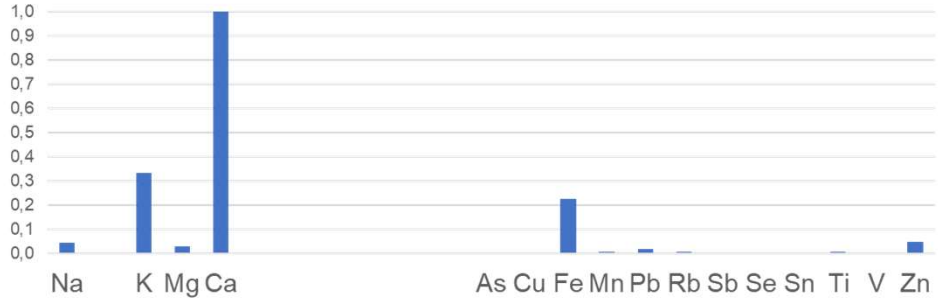
grisa.mocnik@ung.si kristina.glojek@ung.si


GO - ZT - 516
GO - E8 - 084

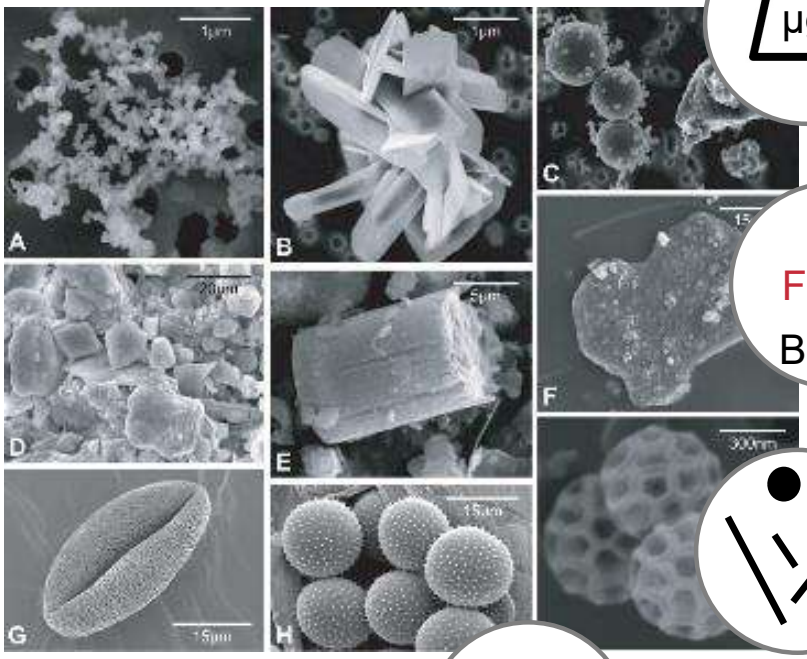

Cement dust
Total species sum (%)
100
80
60
40
20
0
OC
BCff
BCwb
Cl-
NO3-
SO42-
Na+
NH4+
K+
Mg2+
Ca2+
Levoglucosan
2-MT
Oxalate
Polyols
3-MBTCA
Phthalic acid
As
Cd
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Ti
V
Zn


Domestic heating
100
80
60
40
20
0
OC
BCff
BCwb
Cl-
NO3-
SO42-
Na+
NH4+
K+
Mg2+
Ca2+
Levoglucosan
2-MT
Oxalate
Polyols
3-MBTCA
Phthalic acid
As
Cd
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Ti
V
Zn


Mineral dust
Total species sum (%)
100
80
60
40
20
0
OC
BCff
BCwb
Cl-
NO3-
SO42-
Na+
NH4+
K+
Mg2+
Ca2+
Levoglucosan
2-MT
Oxalate
Polyols
3-MBTCA
Phthalic acid
As
Cd
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Ti
V
Zn


1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
Na
K
Mg
Ca
As
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Ti
V
Zn

Različne lastnosti



µg

Masa

Cu
Fe
Al
BC

Sestava

Dimenzije

Topnost

Onesnaženje s PM delci

Največja okoljska grožnja zdravju (WHO, 2021).

PM “škodljivost” ⟷ Cu Fe BC Al sestava ⟷

Alpske doline in problem kakovosti zraka

- Visoki izpusti: 

(e. g. Herich et al., 2014; Glojek et. al., 2022)

- Meteorologija.
- Pomanjkanje raziskav specifičnih ind. virov.
- Proizvodnja cementa: 

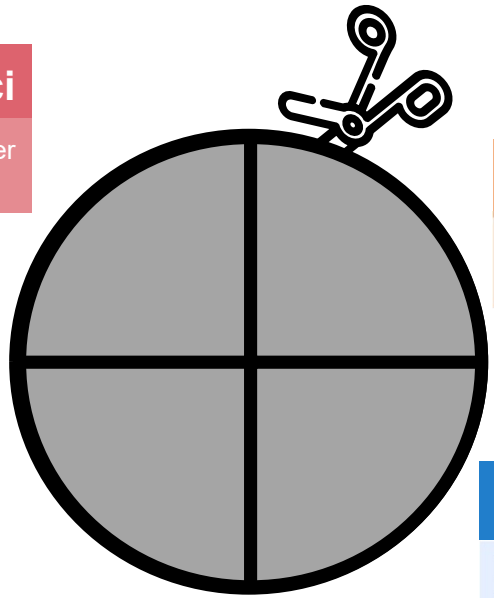
↑ Visoki izpusti in potencialna toksičnost.

(Kim et al., 2003; Rovira et al., 2018; Chen et al., 2022; Ervik et al., 2022).

Foto: Občina Kanal ob Soči

Kemijske analize

Vsak 3. filter, skupaj 120



Ogljični delci

OC/EC, Thermooptical analyzer

Ioni

Ion chromatography (IC).

Organski sledilci

IC and HPLC-PAD.

Kovine

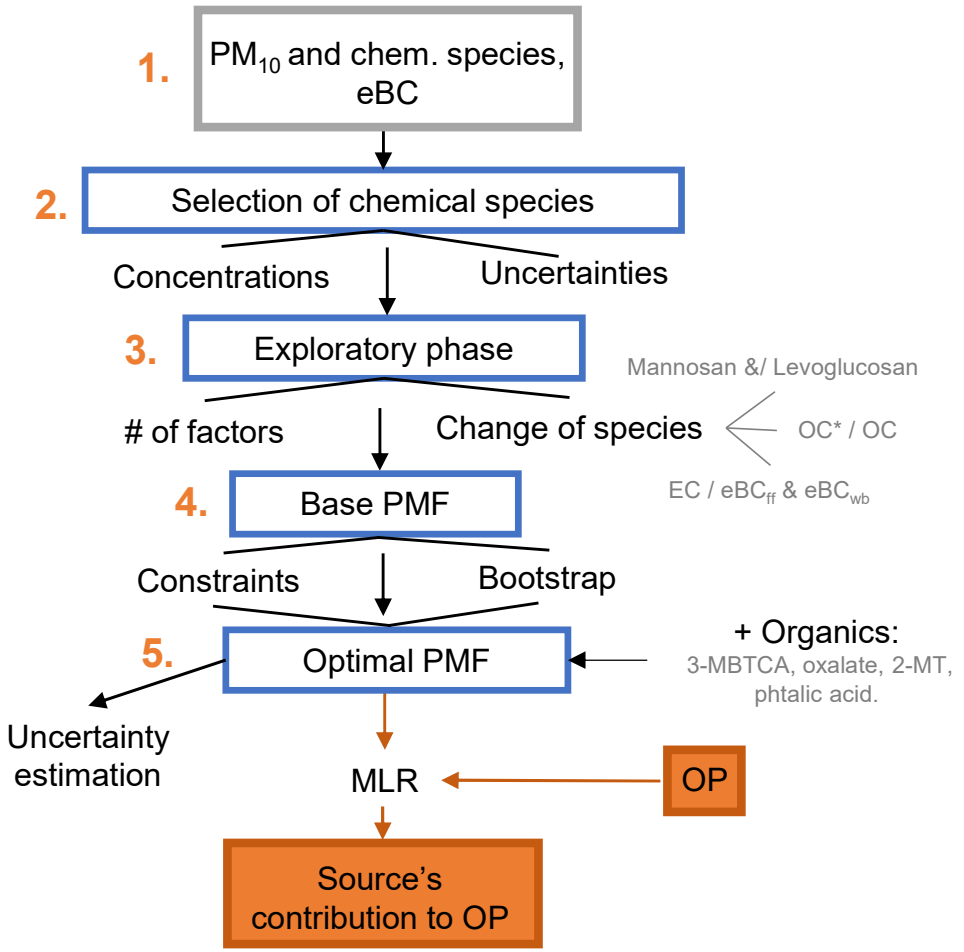
Inductively coupled plasma mass spectroscopy (ICP-MS).

Oksidativni potencial

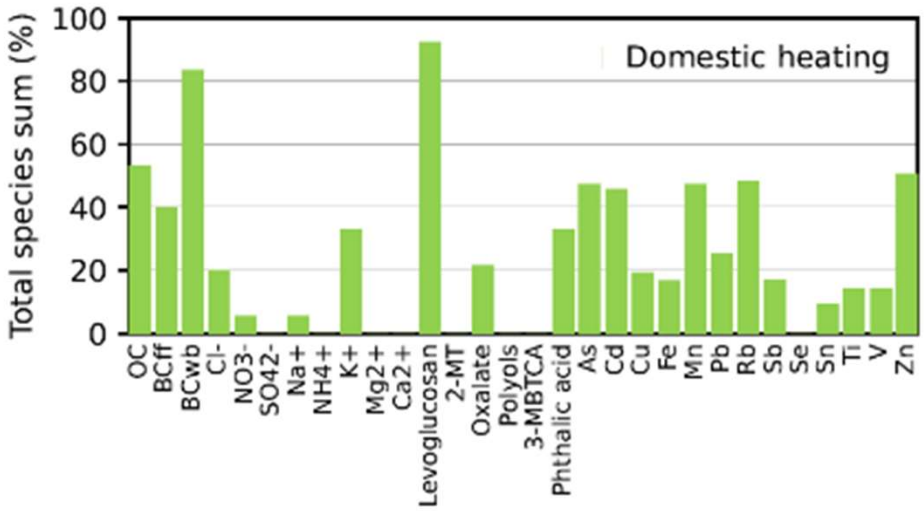
Askorbinska kislina (AA), dithiothreitol (DTT)

Pozitivna Matrična Faktorizacija (PMF): koraki

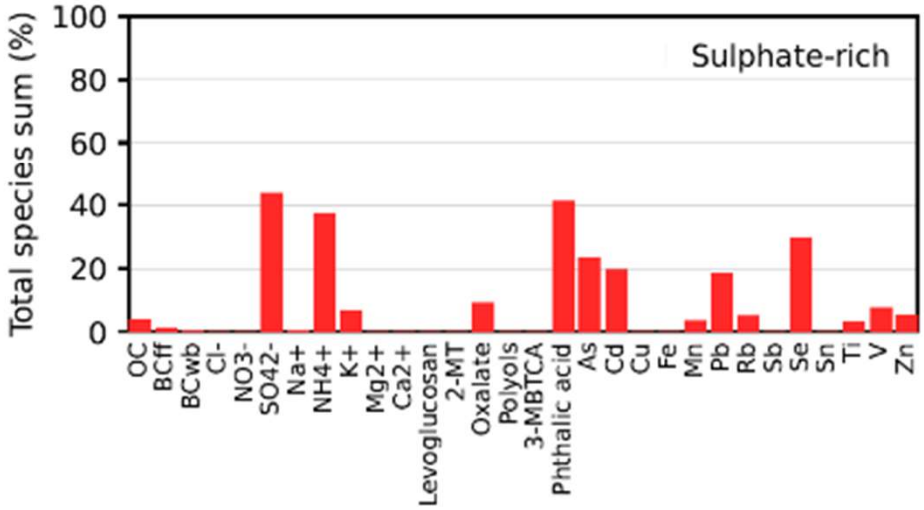
Software: EPA PMF 5.0

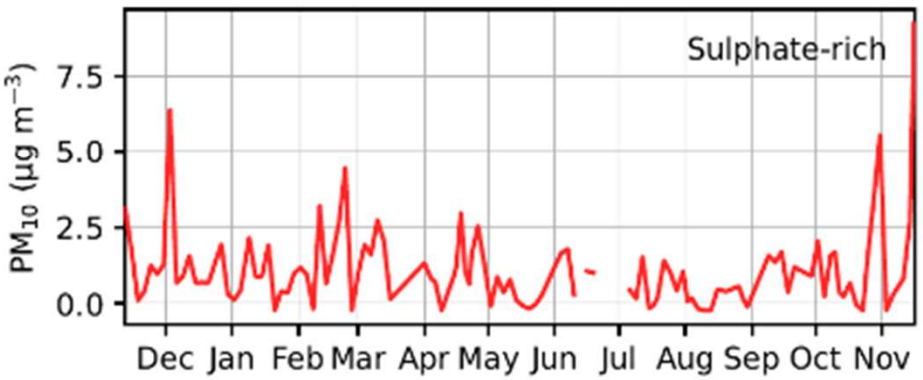


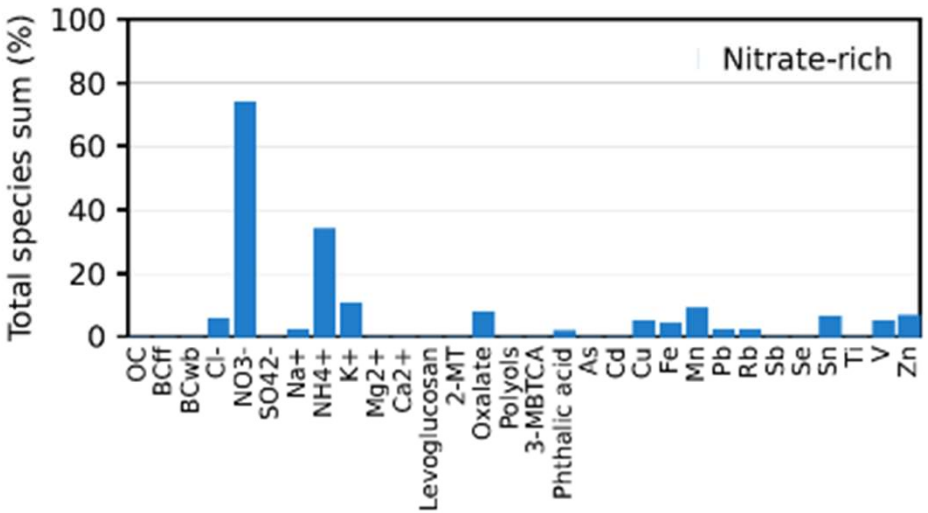
LEGEND:
eBC – equivalent black carbon
OP – oxidative potential
MLR - multiple linear regression

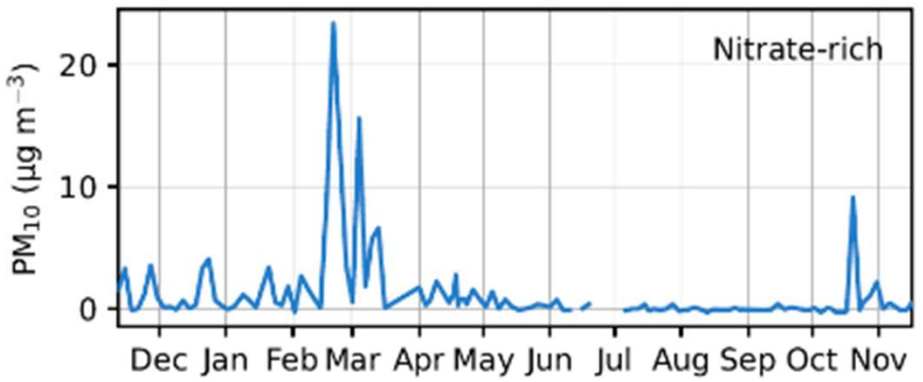

Domestic heating
Total species sum (%)
0
20
40
60
80
100
OC
BCff
BCwb
Cl-
NO3-
SO42-
Na+
NH4+
K+
Mg2+
Ca2+
Levoglucosan
2-MT
Oxalate
Polyols
3-MBTCA
Phthalic acid
As
Cd
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Ti
V
Zn

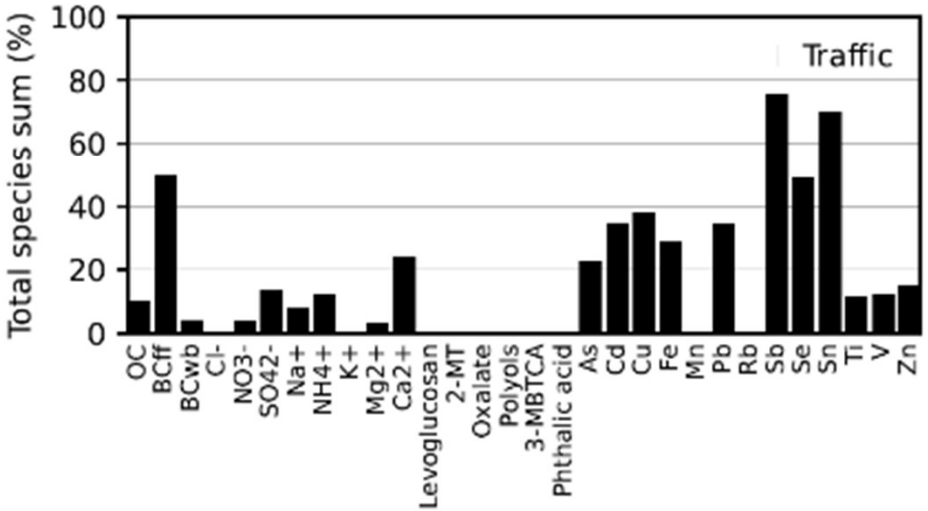

Domestic heating
PM10 (µg m−3)
0
10
20
30
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

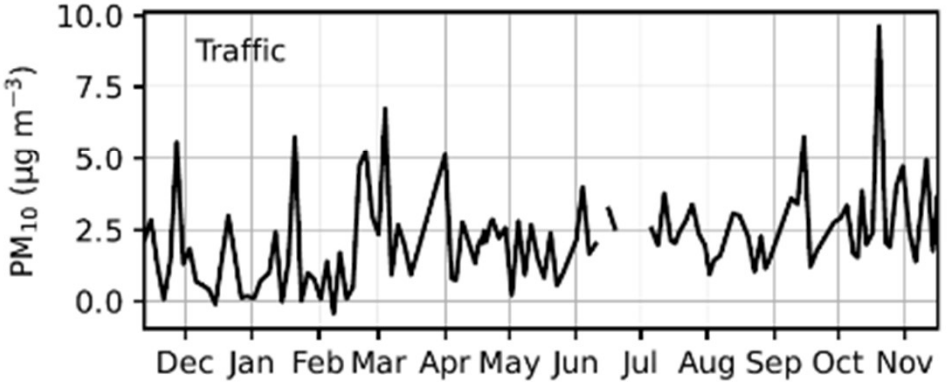

Sulphate-rich
Total species sum (%)
0
20
40
60
80
100
OC
BCff
BCwb
Cl-
NO3-
SO42-
Na+
NH4+
K+
Mg2+
Ca2+
Levoglucosan
2-MT
Oxalate
Polyols
3-MBTCA
Phthalic acid
As
Cd
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Ti
V
Zn

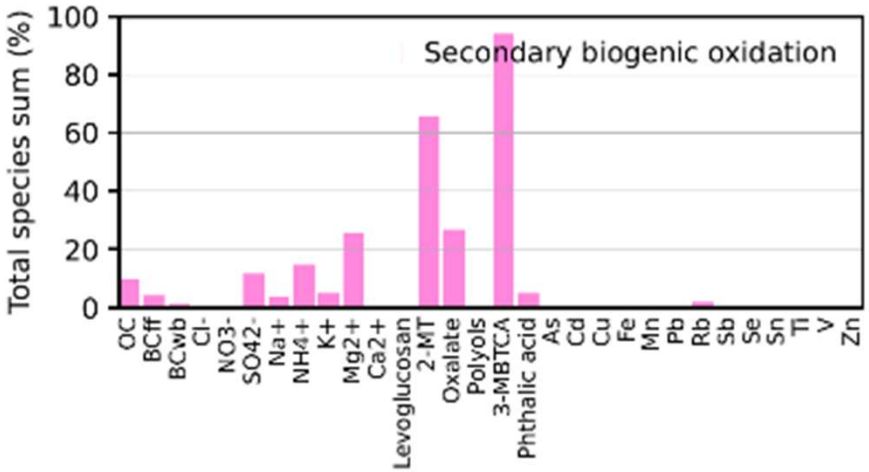

Sulphate-rich
PM10 (µg m−3)
0.0
2.5
5.0
7.5
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

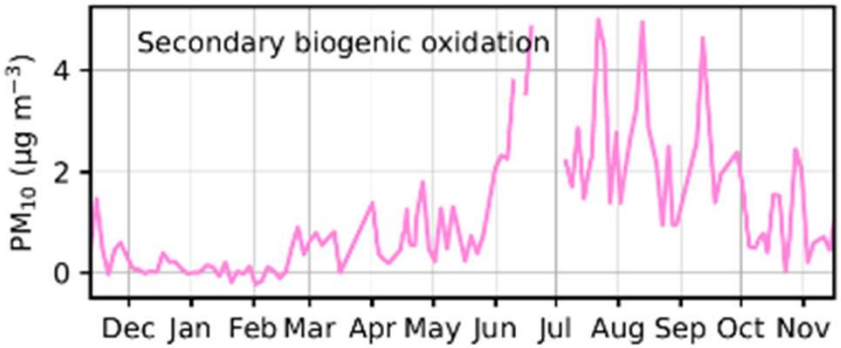

Nitrate-rich
Total species sum (%)
100
80
60
40
20
0
OC
BCff
BCwb
Cl-
NO3-
SO42-
Na+
NH4+
K+
Mg2+
Ca2+
Levoglucosan
2-MT
Oxalate
Polyols
3-MBTCA
Phthalic acid
As
Cd
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Ti
V
Zn

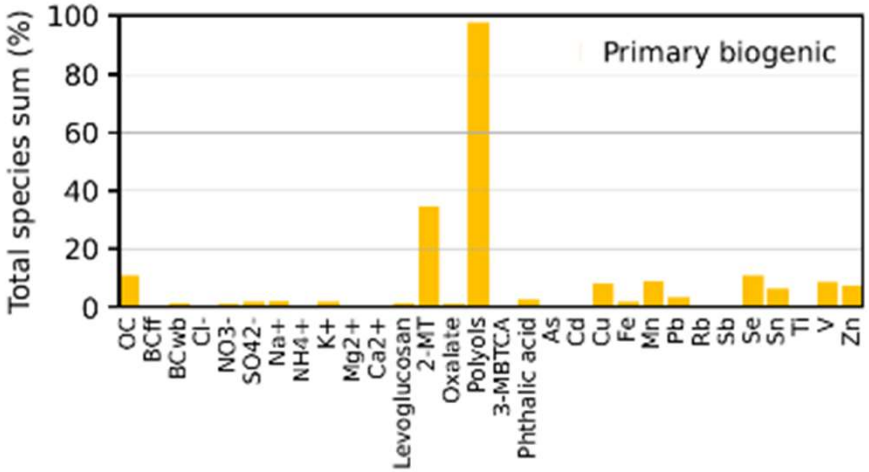

Nitrate-rich
PM10 (µg m−3)
20
10
0
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

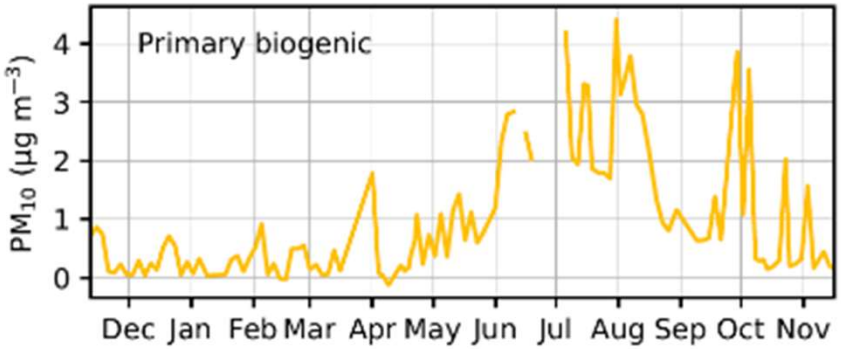

Traffic
Total species sum (%)
100
80
60
40
20
0
OC
BCff
BCwb
Cl-
NO3-
SO42-
Na+
NH4+
K+
Mg2+
Ca2+
Levoglucosan
2-MT
Oxalate
Polyols
3-MBTCA
Phthalic acid
As
Cd
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Ti
V
Zn

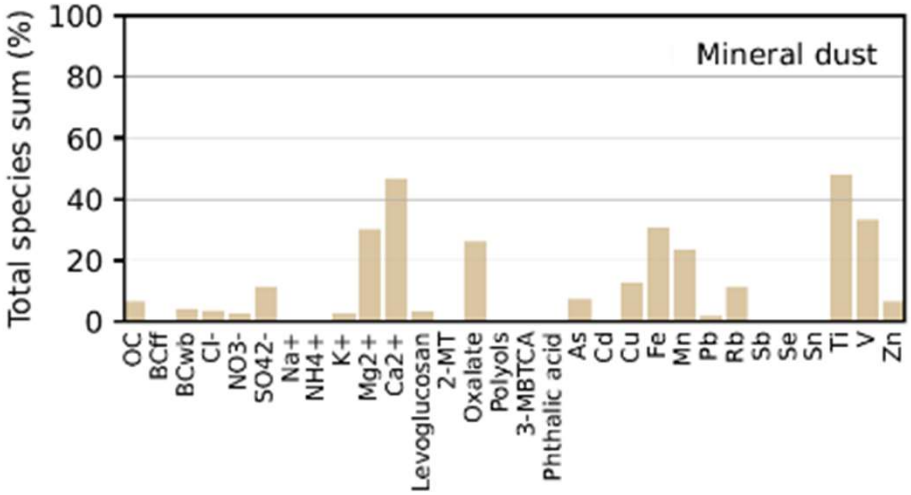

Traffic
PM10 (µg m−3)
10.0
7.5
5.0
2.5
0.0
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

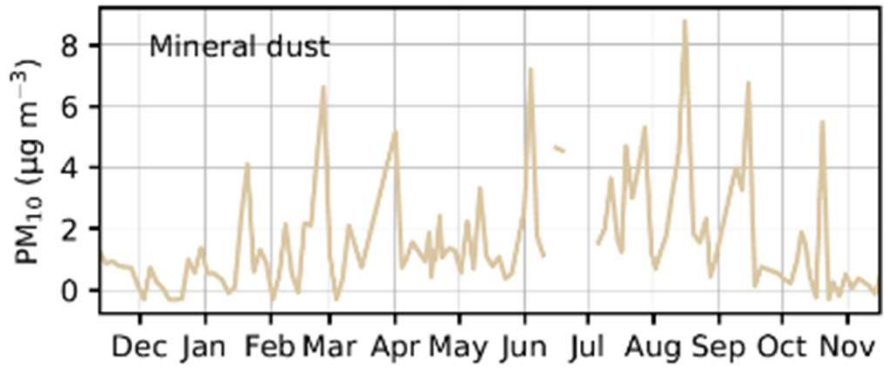

Secondary biogenic oxidation
Total species sum (%)
0
20
40
60
80
100
OC
BCff
BCwb
Cl-
NO3-
SO42-
Na+
NH4+
K+
Mg2+
Ca2+
Levoglucosan
2-MT
Oxalate
Polyols
3-MBTCA
Phthalic acid
As
Cd
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Tl
V
Zn

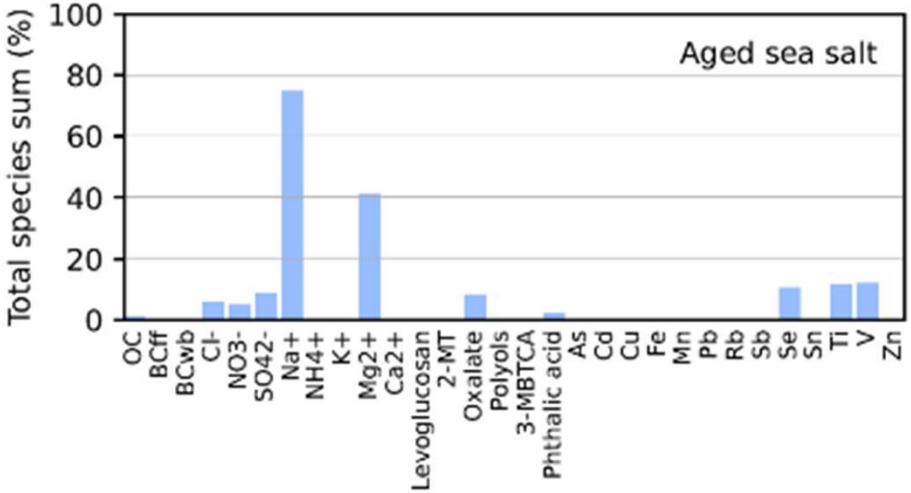

Secondary biogenic oxidation
PM10 (µg m−3)
0
2
4
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

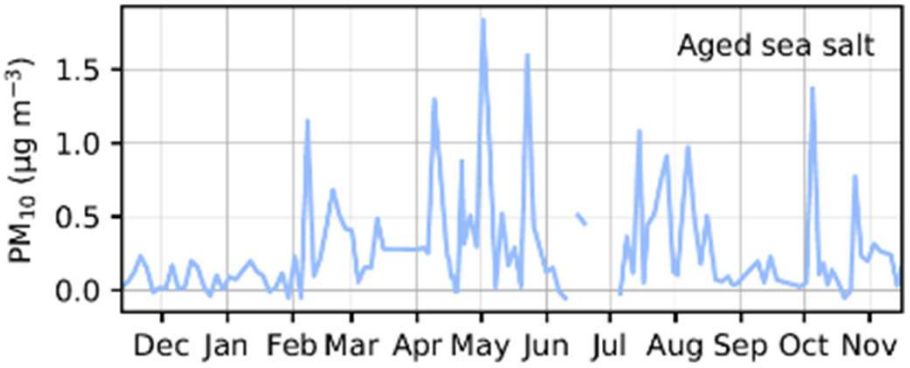

Primary biogenic
Total species sum (%)
0
20
40
60
80
100
OC
BCff
BCwb
Cl-
NO3-
SO42-
Na+
NH4+
K+
Mg2+
Ca2+
Levoglucosan
2-MT
Oxalate
Polyols
3-MBTCA
Phthalic acid
As
Cd
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Tl
V
Zn


Primary biogenic
PM10 (µg m−3)
0
1
2
3
4
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

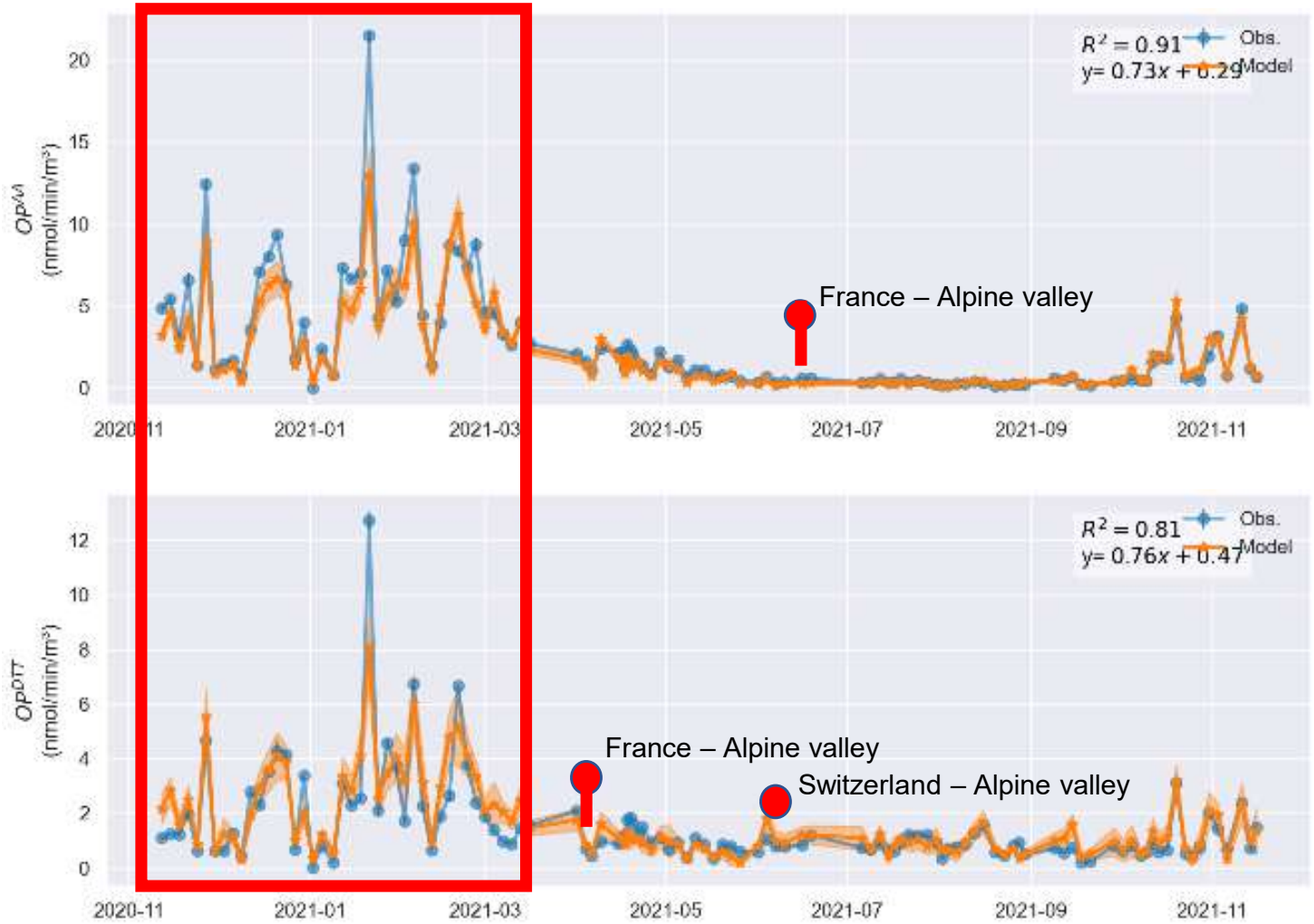

Mineral dust
Total species sum (%)
100
80
60
40
20
0
OC
BCff
BCwb
Cl-
NO3-
SO42-
Na+
NH4+
K+
Mg2+
Ca2+
Levoglucosan
2-MT
Oxalate
Polyols
3-MBTCA
Phthalic acid
As
Cd
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Ti
V
Zn


Mineral dust
PM10 (µg m−3)
8
6
4
2
0
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov


Aged sea salt
Total species sum (%)
100
80
60
40
20
0
OC
BCff
BCwb
Cl-
NO3-
SO42-
Na+
NH4+
K+
Mg2+
Ca2+
Levoglucosan
2-MT
Oxalate
Polyols
3-MBTCA
Phthalic acid
As
Cd
Cu
Fe
Mn
Pb
Rb
Sb
Se
Sn
Ti
V
Zn


Aged sea salt
PM10 (µg m−3)
1.5
1.0
0.5
0.0
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

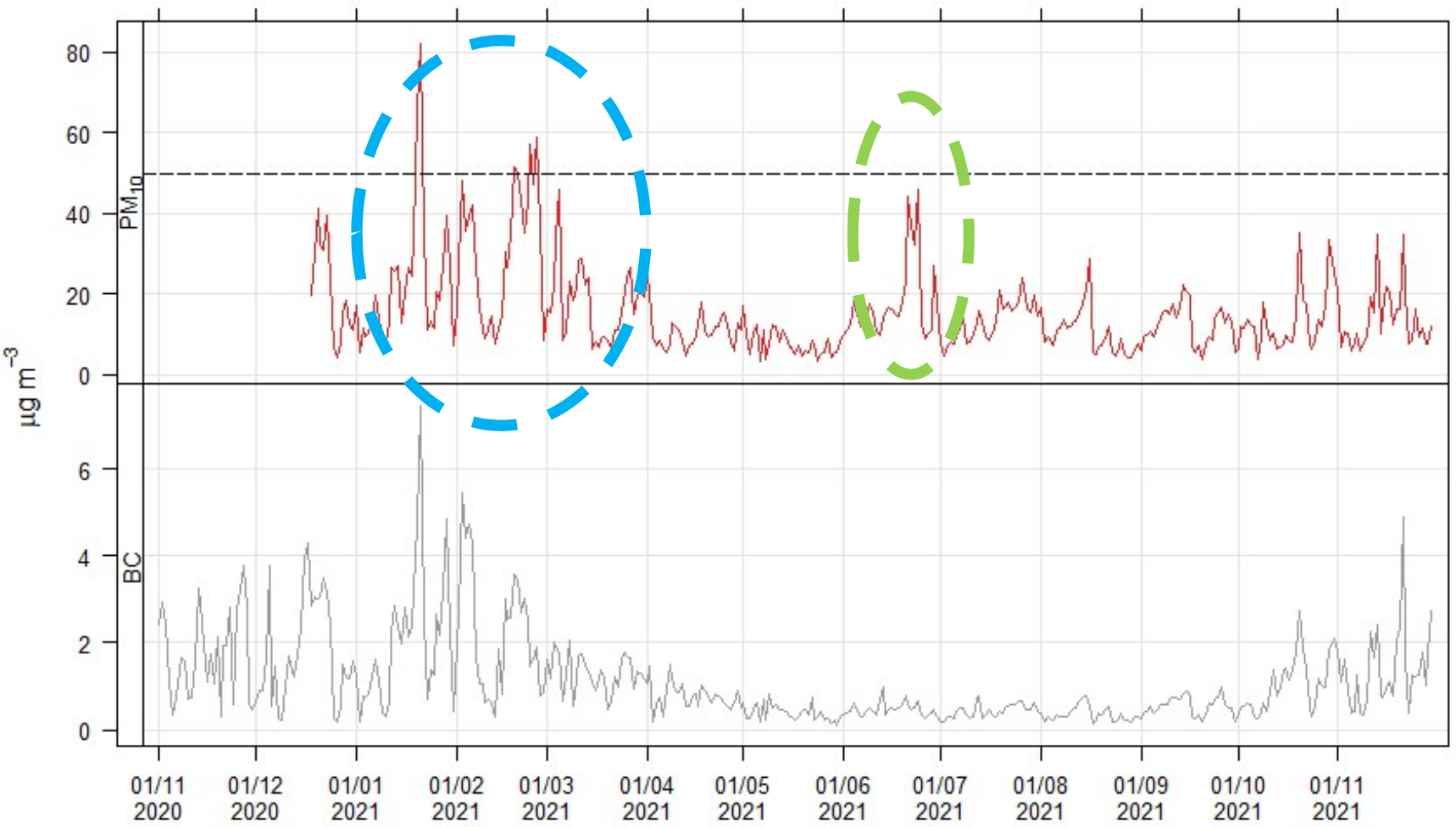
Oxidative potential (OP)

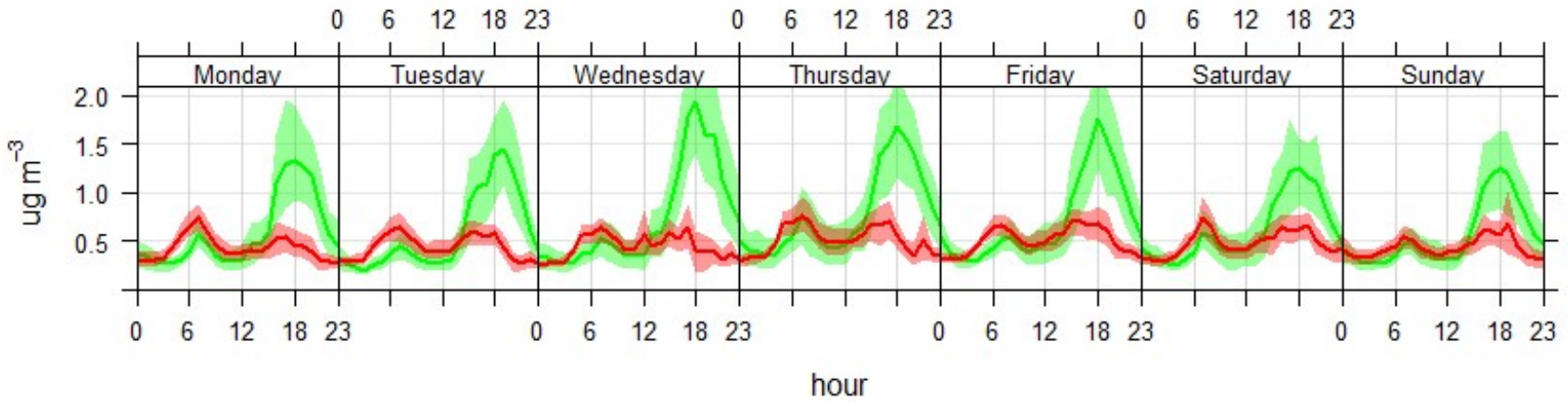


OP^{AA}

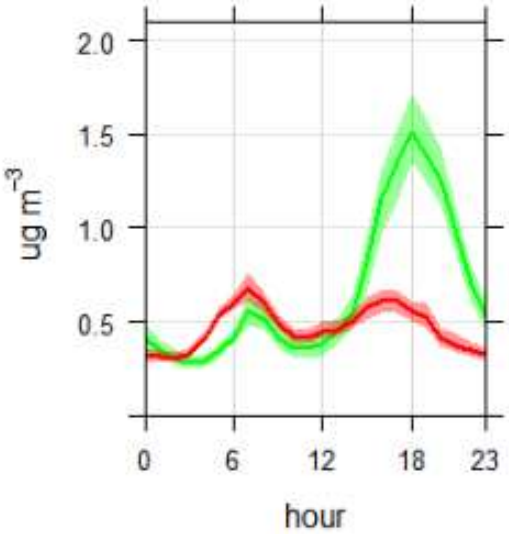
OP^{DTT}

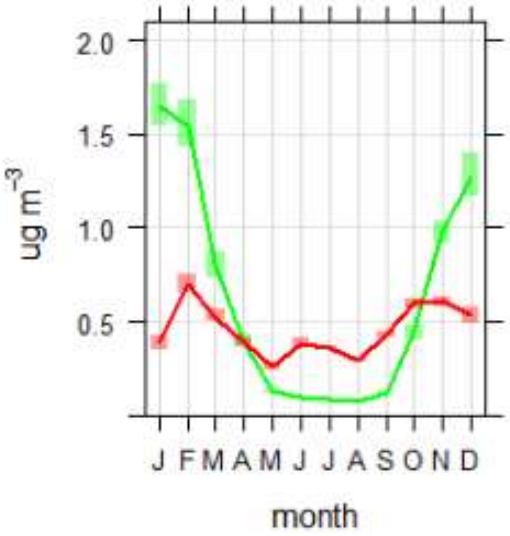
PM_{10}, BC

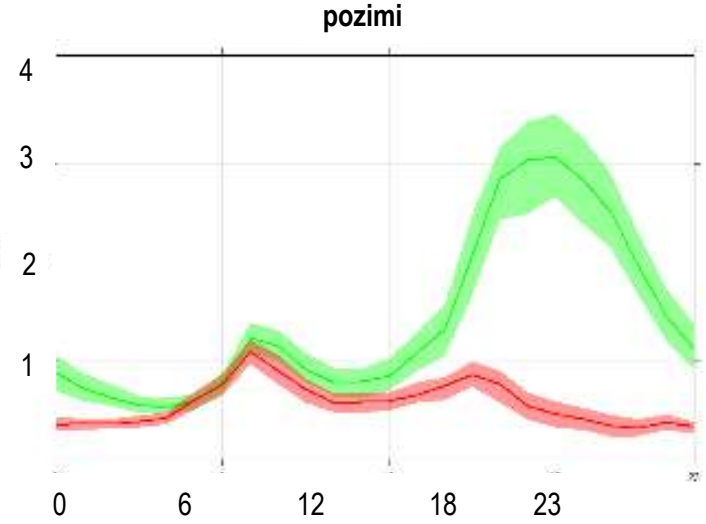

PM10
BC
µg m-3
80
60
40
20
0
6
4
2
0
01/11 2020
01/12 2020
01/01 2021
01/02 2021
01/03 2021
01/04 2021
01/05 2021
01/06 2021
01/07 2021
01/08 2021
01/09 2021
01/10 2021
01/11 2021


Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
ug m^{-3}
hour

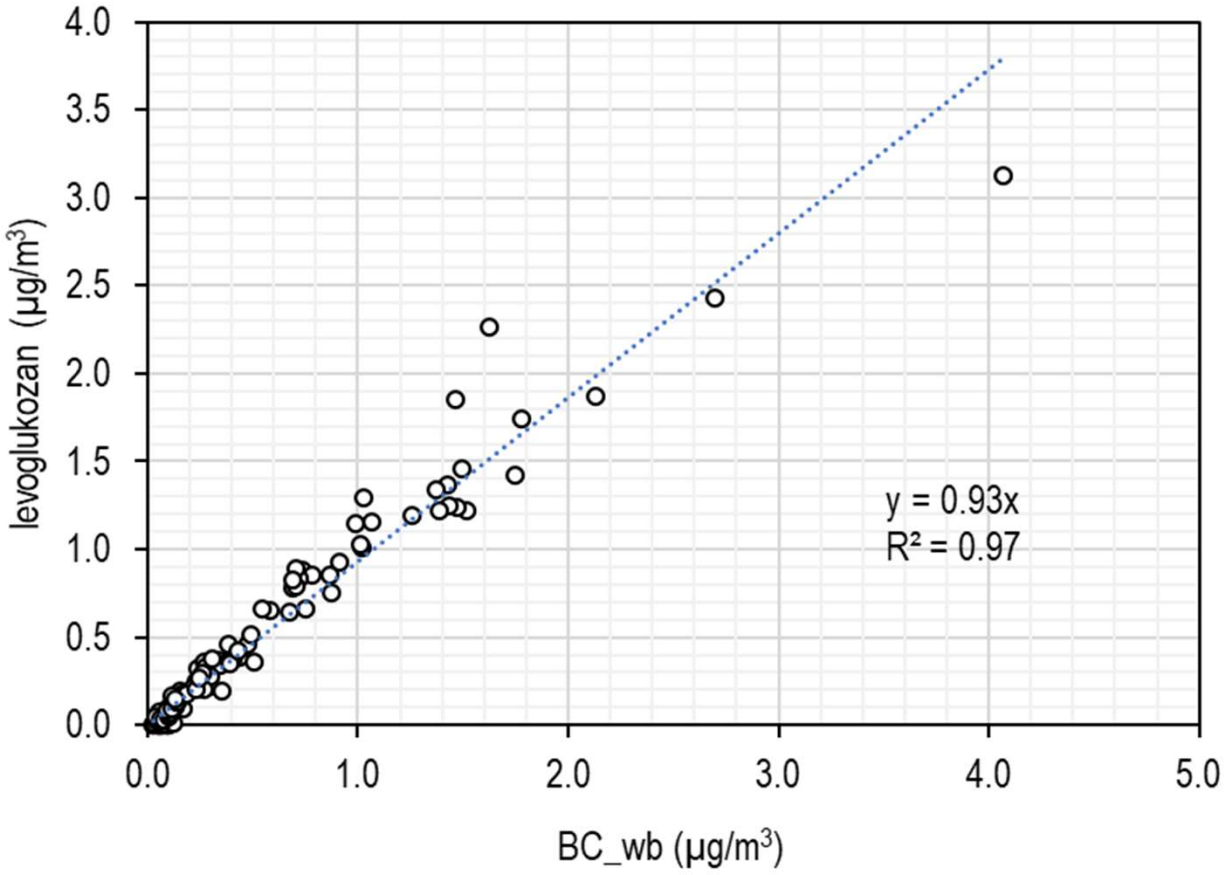

BC_wb
BC_ff


ug m^{-3}
hour

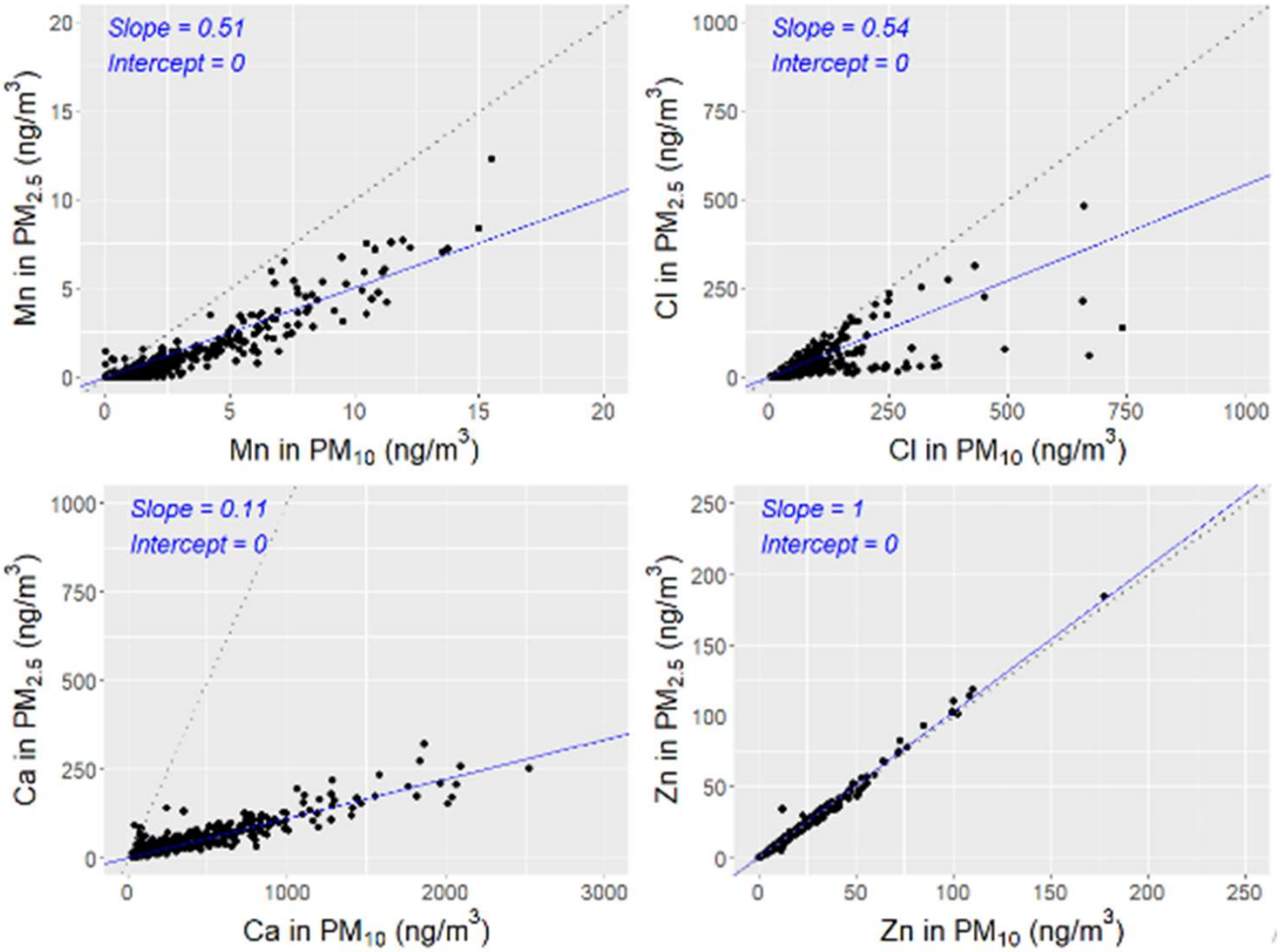

ug m^{-3}
J F M A M J J A S O N D
month

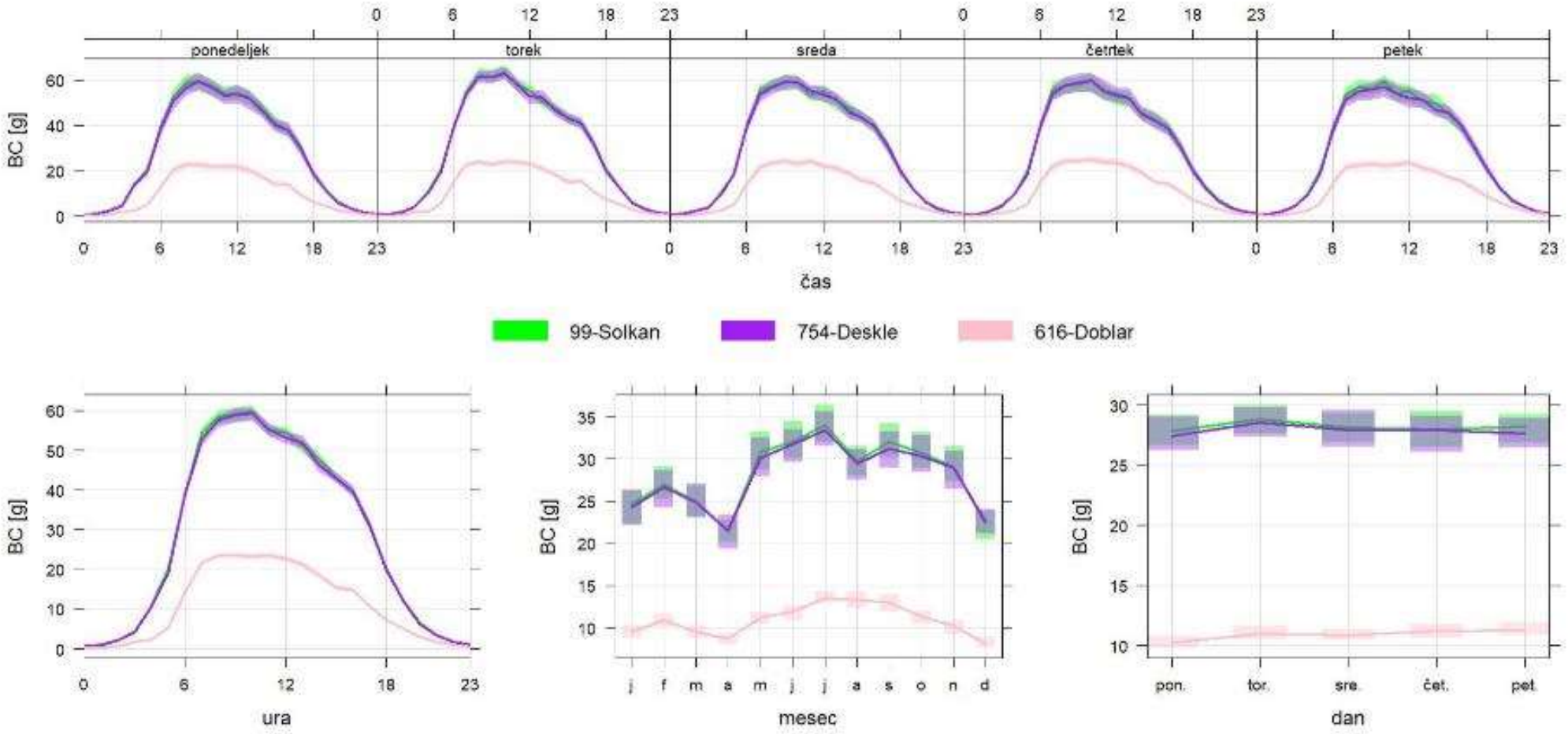

pozimi

eBC and sources



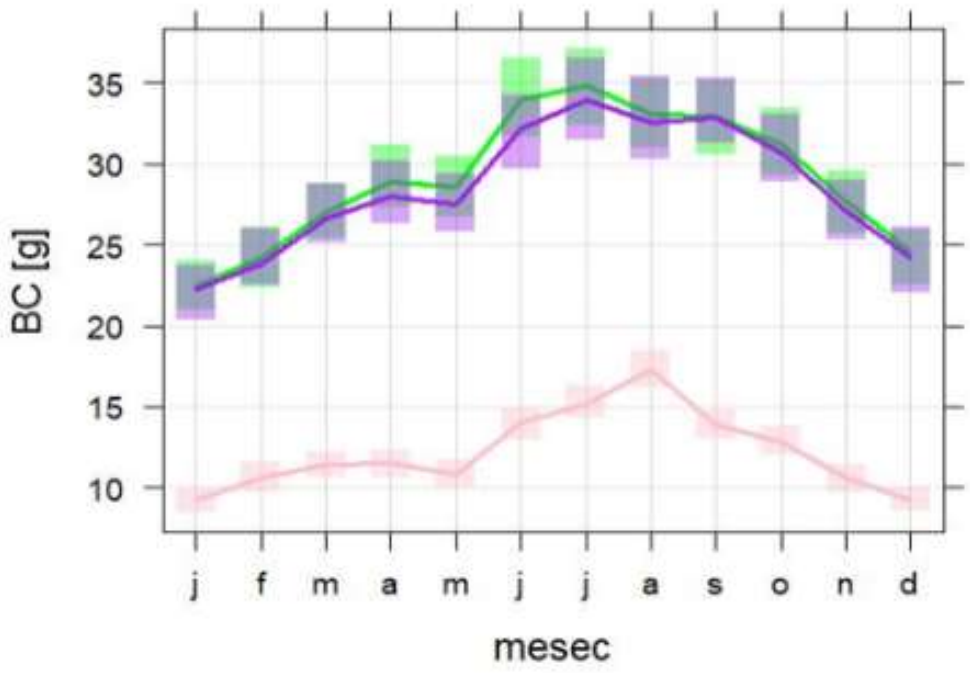
Primerjava kovin fine in grobe frakcije



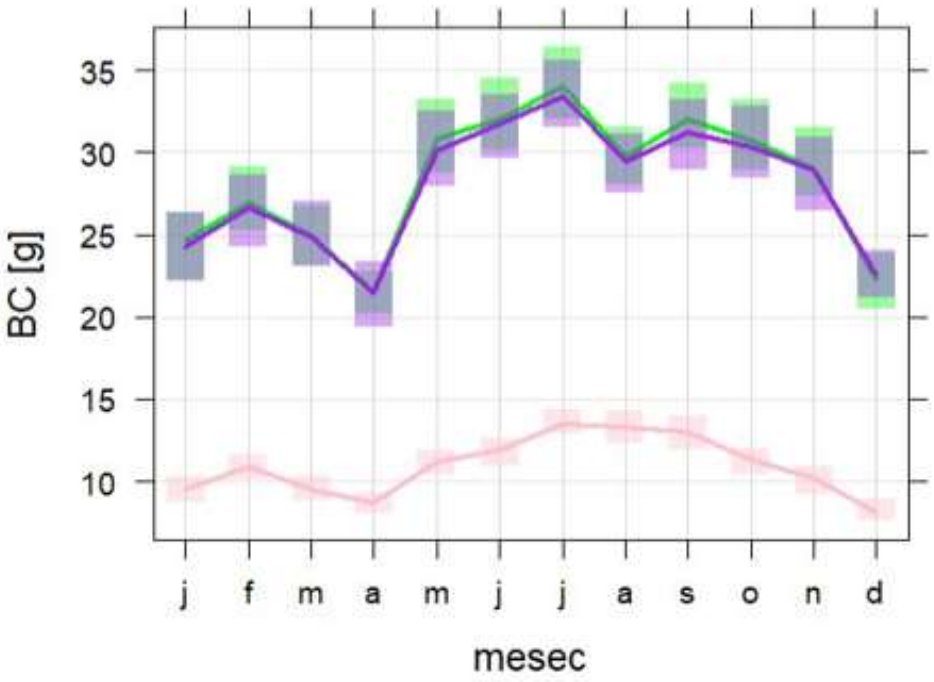


2020
Podkoritnik, 2022

2019

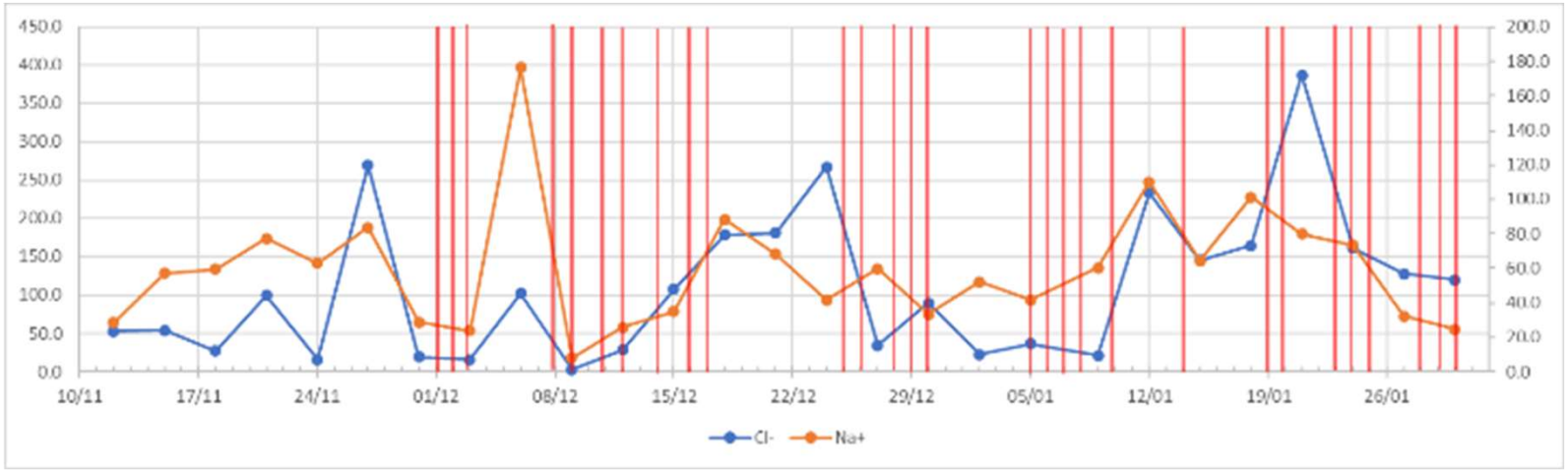


2020



Podkoritnik, 2022

Soljenje cest



PMF formulas

$x_{ij} = \sum_{k=1}^{p} g_{ik} f_{kj} + e_{ij}$

x_{ij} – concentration of species j measured on sample i

p – the number of factors contributing to the sample

f_{kj} – the concentration of species j in factor profile k

g_{ik} – the relative contribution of factor k to sample I

e_{ij} – the residual of the PMF model for the j^{th} species measured on sample i.

The values of g_{ik} and f_{kj} are adjusted until a minimum value of the objective function Q for a user-selected p is found.

$$Q = \sum_{j=1}^{m} \sum_{i=1}^{n} \frac{{e_{ij}}^2}{{s_{ij}}^2}$$

s_{ij} – the uncertainty of the j^{th} species concentration in sample I

n – the number of samples

m – the number of species.