GIORNATE DI STUDIO

LA CARATTERIZZAZIONE CHIMICA DEL PARTICOLATO ATMOSFERICO

V EDIZIONE

Terni, 21-22 Novembre 2022

Approccio sperimentale innovativo per la mappatura spaziale del contributo al rischio di sorgenti emissive di elementi in traccia potenzialmente tossici nel PM_{10}

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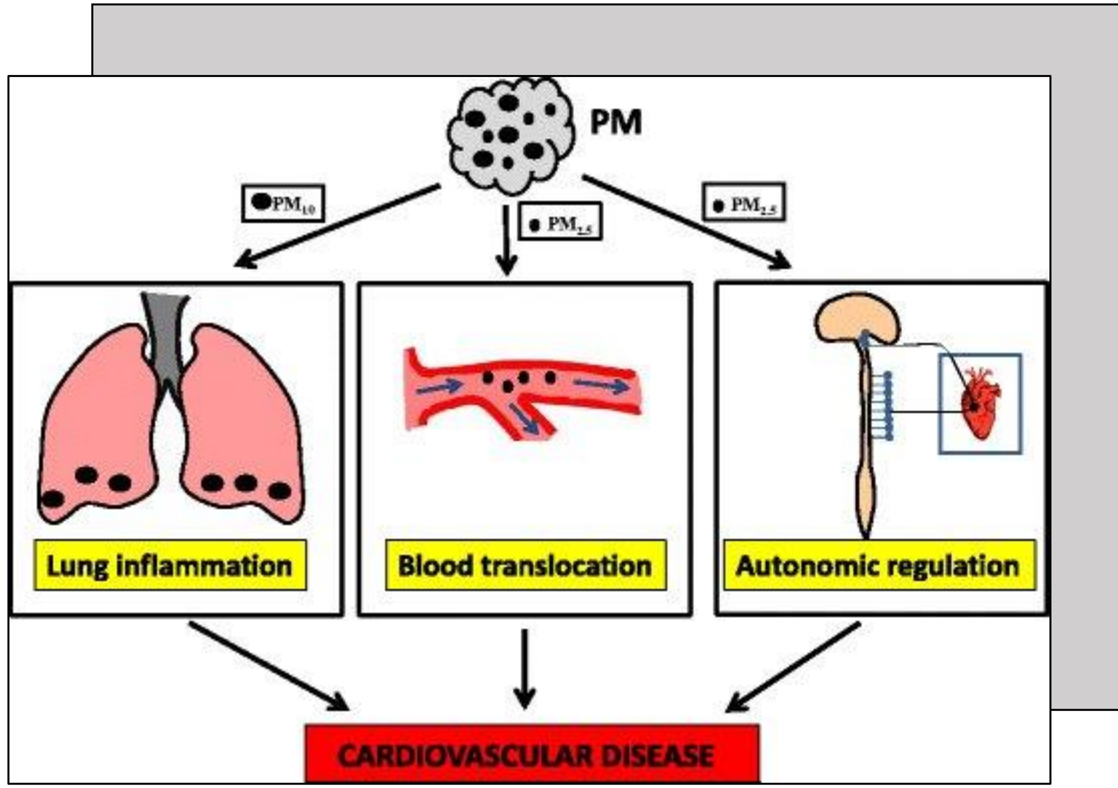
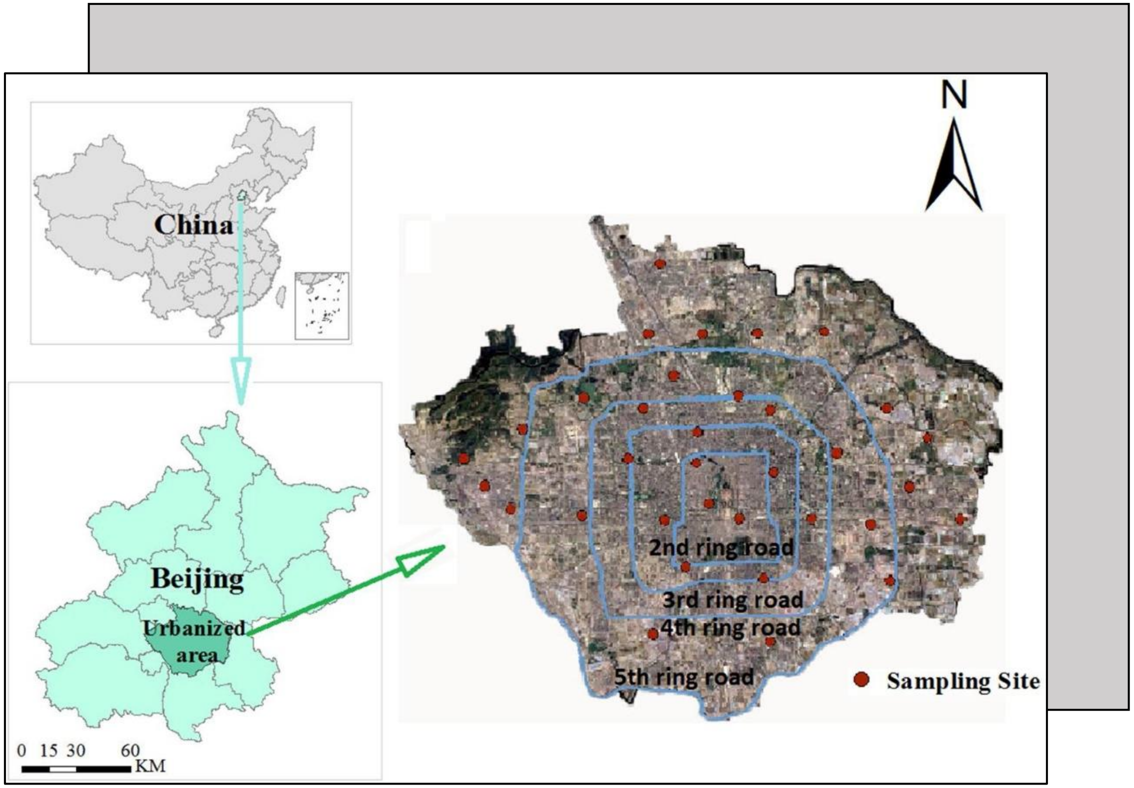
Exposure to potentially toxic trace elements (PTTEs) in inhalable particulate matter (PM_{10}) is associated with an increased risk of developing cardiorespiratory diseases



Fiordelisi, A., Piscitelli, P., Trimarco, B., Coscioni, E., Iaccarino, G., Sorriento, D. 2017. The mechanisms of air pollution and particulate matter in cardiovascular diseases. Heart failure reviews, 22(3), 337-347. DOI: 10.1007/s10741-017-9606-7

In multi-source polluted urban contexts, a spatially-resolved evaluation of health risks associated with exposure to PTTEs in PM is essential to identify critical source areas

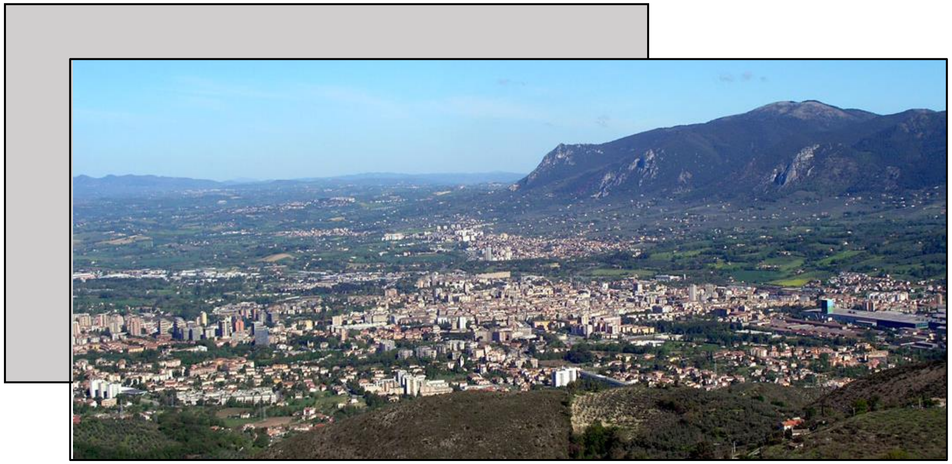


Men, C., Liu, R., Xu, L., Wang, Q., Guo, L., Miao, Y., Shen, Z. 2020. Source-specific ecological risk analysis and critical source identification of heavy metals in road dust in Beijing, China. Journal of Hazardous Materials, 388, 121763. DOI: 10.1016/j.jhazmat.2019.121763


INGRESSO HOTEL
HOTELEINGANG
HOTEL ENTRANCE

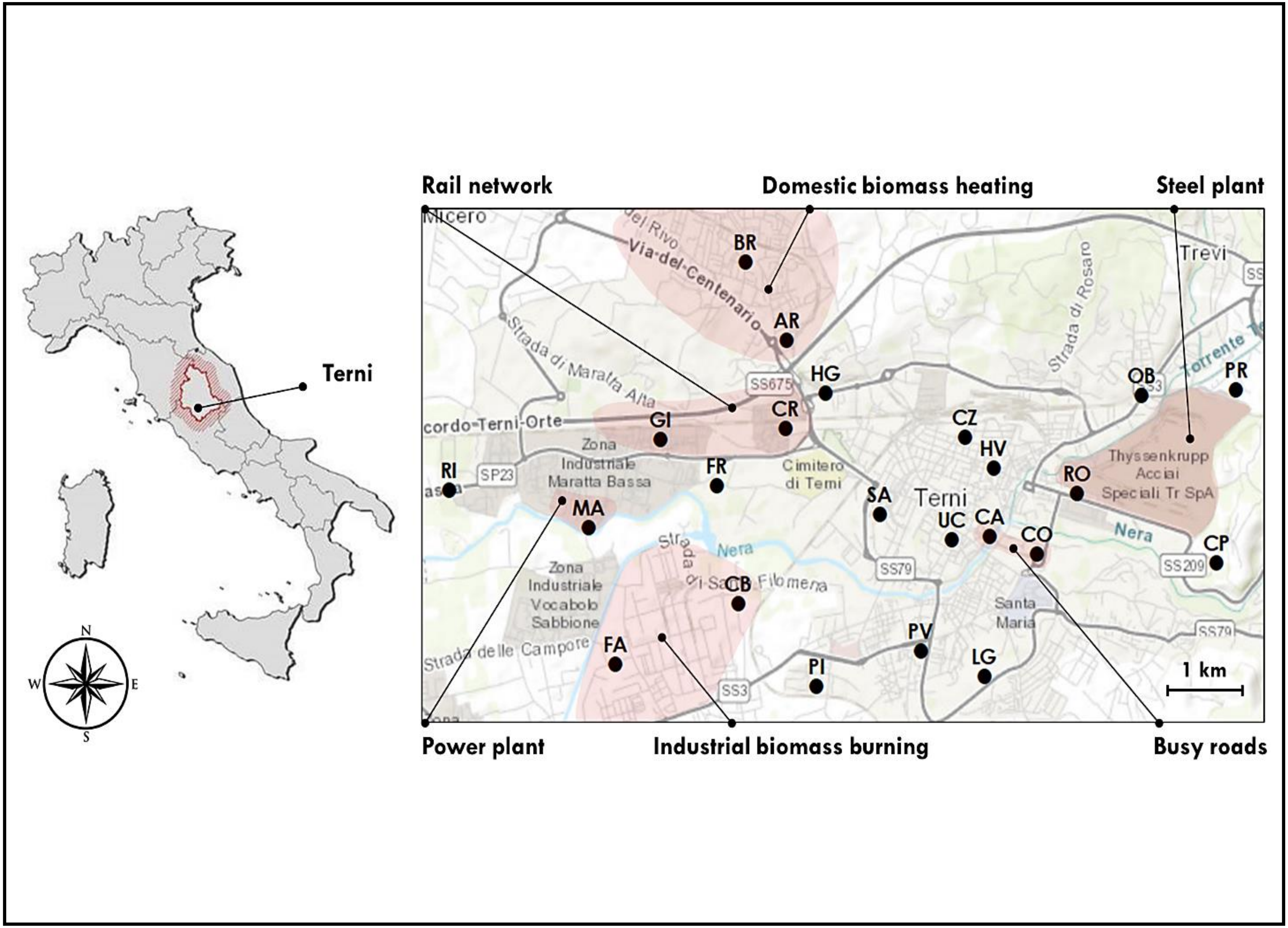
TERNI
Central Italy

19/11/2016 - 19/02/2018

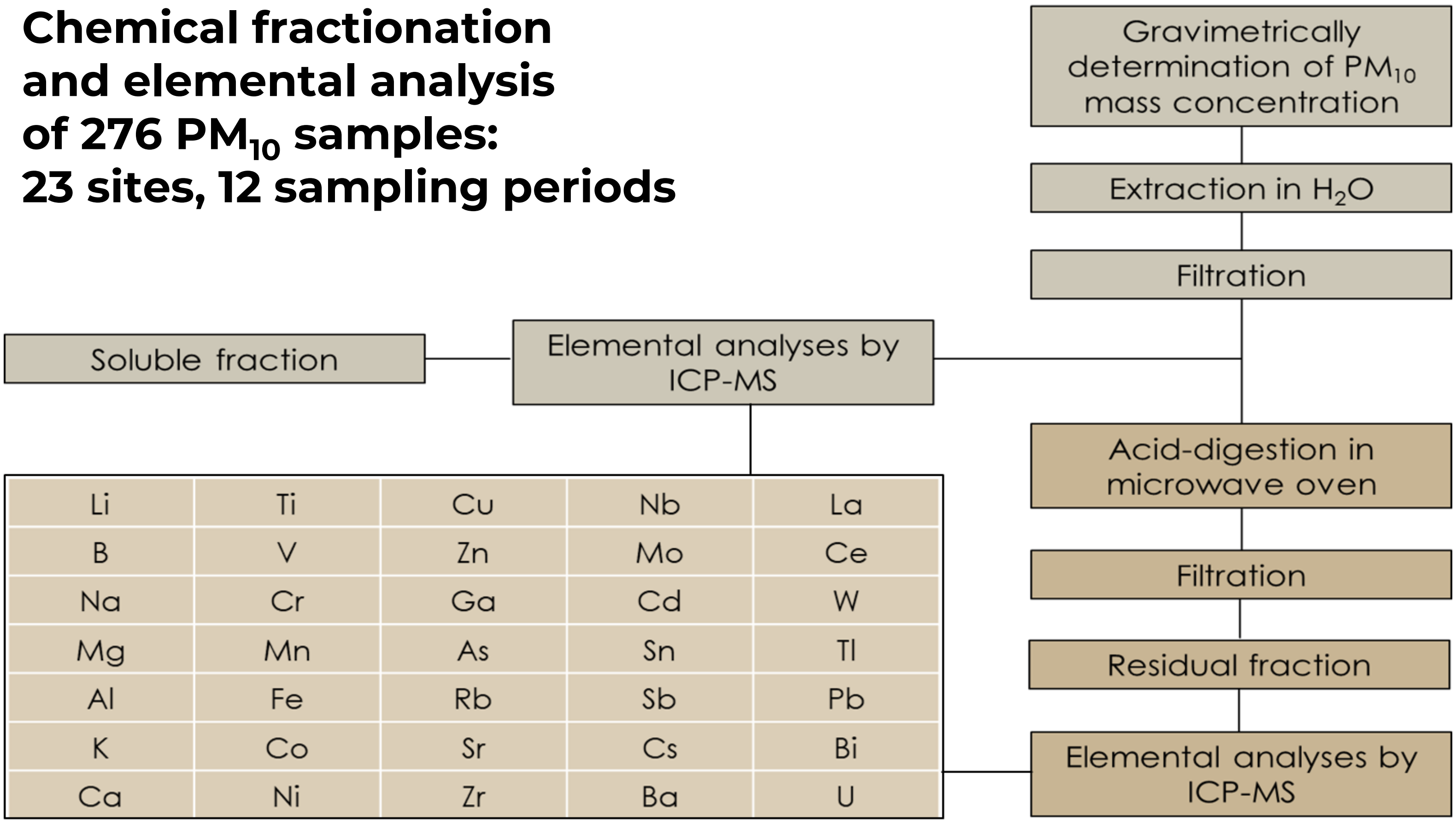


TERNI
Central Italy

Urban and industrial PM emission sources:


Terni
N
S
W
E
Rail network
Domestic biomass heating
Steel plant
Power plant
Industrial biomass burning
Busy roads
BR
AR
HG
CR
GI
FR
RI
MA
CB
FA
PI
PV
LG
SA
UC
CA
CO
CZ
HV
RO
OB
PR
CP
1 km
Thyssenkrupp Acciai Speciali Tr SpA
Zona Industriale Maratta Bassa
Zona Industriale Vocabolo Sabbione
Cimitero di Terni
Santa Maria
Via-del-Centenario
Strada di Maratta Alta
Strada di Rosaro
Strada delle Campore
Strada di Santa Filomena
Nera
Torrente
Trevi
SS675
SP23
SS79
SS3
SS209

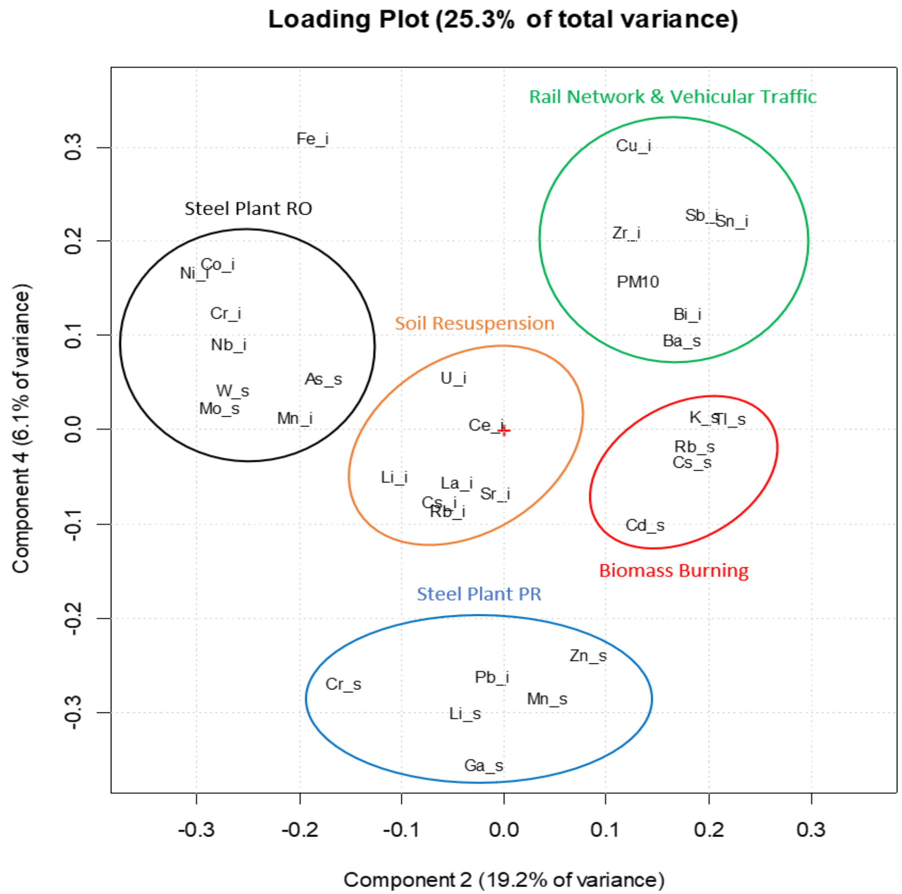
Chemical fractionation and elemental analysis of 276 PM_{10} samples: 23 sites, 12 sampling periods



Li	Ti	Cu	Nb	La
B	V	Zn	Mo	Ce
Na	Cr	Ga	Cd	W
Mg	Mn	As	Sn	Tl
Al	Fe	Rb	Sb	Pb
K	Co	Sr	Cs	Bi
Ca	Ni	Zr	Ba	U

PCA
PC2/PC4

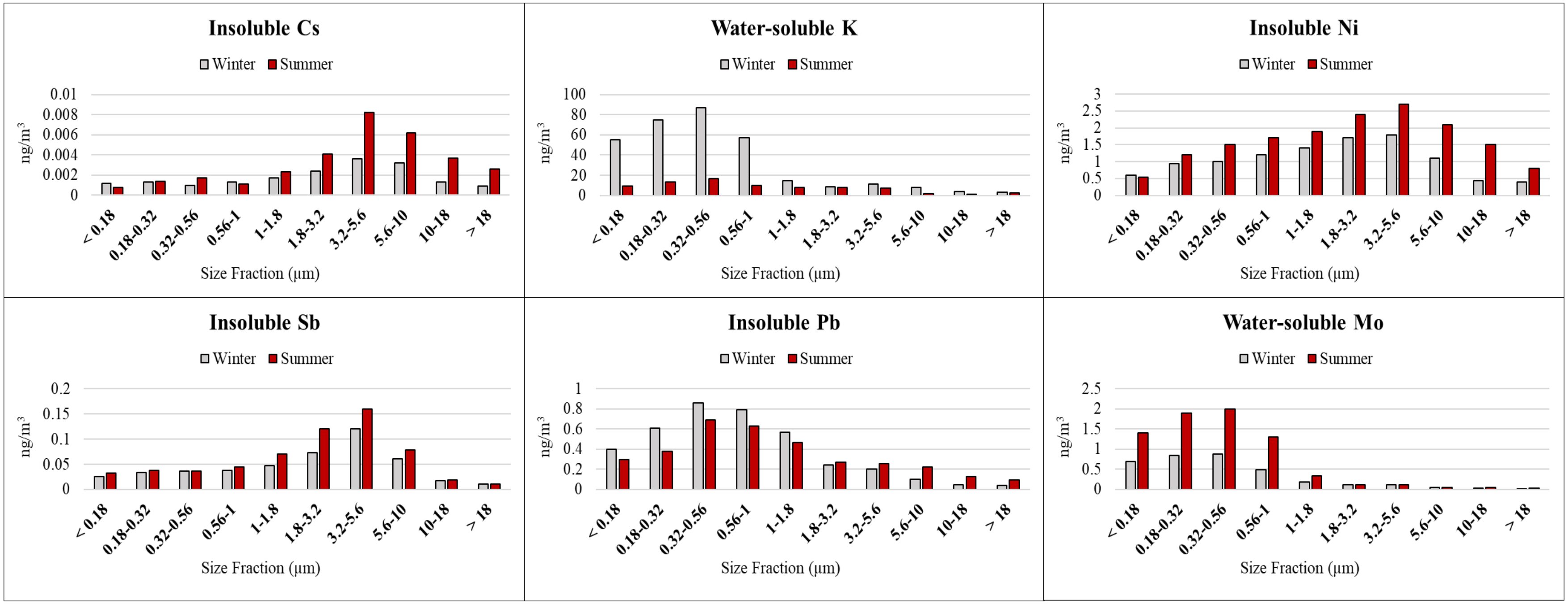
Different clusters of chemically fractionated elements trace the main local PM_{10} emission sources in Terni



Massimi, L.*, Ristorini, M., Astolfi, M. L., Perrino, C., Canepari, S. 2020. High resolution spatial mapping of element concentrations in PM10: A powerful tool for localization of emission sources. Atmospheric Research, 105060. DOI: 10.1016/j.atmosres.2020.105060

Size Distribution Analysis

Water-soluble and Insoluble Elements



Massimi, L.*, Ristorini, M., Astolfi, M. L., Perrino, C., Canepari, S. 2020. High resolution spatial mapping of element concentrations in PM10: A powerful tool for localization of emission sources. Atmospheric Research, 105060. DOI: 10.1016/j.atmosres.2020.105060

Risk Assessment of PTTEs in PM_{10}

Carcinogenic Risk (CR)

$$\mathbf{CR} = \frac{\mathbf{C} * \mathbf{ET} * \mathbf{EF} * \mathbf{ED} * \mathbf{IUR}}{\mathbf{AT}}$$

Non-carcinogenic Risk (NCR)

$$\mathbf{NCR} = \frac{(\mathbf{C} * \mathbf{IR} * \mathbf{CF} * \mathbf{EF} * \mathbf{ED})/(\mathbf{BW} * \mathbf{AT})}{\mathbf{RfD_{inh}}}$$

where C is the average concentration of element species (μg m^{-3}), ET is the exposure time (12 h day^{-1}), EF is the exposure frequency (days $year^{-1}$), ED is the exposure duration average time (years), AT is the average time (years), IUR is the inhalation unit risk (μg m^{-3})$^{-1}$ of the trace element. IR is the rate of air inhalation as 10 m^3 day^{-1} for children and 20 m^3 day^{-1} for adults, CF is a unit correction factor as 0.001, EF is the relative exposure frequency (days $year^{-1}$), BW is the body weight assumed as 15 kg for children and 70 kg for adults, and RfD_{inh} is the reference exposure level.

As, Cr_s, Ni, Pb

Cd, Co, Cr, Cu, Mn, Ni, Sb, Pb, Zn

USEPA (United States Environmental Protection Agency). 2009. Risk assessment guidance for superfund volume I: human health evaluation manual (part F, supplemental guidance for inhalation risk assessment). Office of Superfund Remediation and Technology Innovation, Washington, D.C. https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part-f

Carcinogenic risk

	RI	MA	FA	GI	FR	CB	PI	BR	AR	CR	HG	SA	PV	LG	CZ	HV	UC	CA	CO	RO	OB	PR	CP	AM	SD
As	4 10 -8	5 10 -8	6 10 -8	5 10 -8	5 10 -8	5 10 -8	5 10 -8	5 10 -8	5 10 -8	4 10 -8	5 10 -8	5 10 -8	5 10 -8	5 10 -8	7 10 -8	6 10 -8	5 10 -8	6 10 -8	6 10 -8	1 10 -7	6 10 -8	7 10 -8	5 10 -8	5 10 -8	2 10 -8
Cr_s	2 10 -7	2 10 -7	2 10 -7	2 10 -7	2 10 -7	3 10 -7	3 10 -7	3 10 -7	3 10 -7	2 10 -7	3 10 -7	3 10 -7	3 10 -7	3 10 -7	3 10 -7	3 10 -7	3 10 -7	4 10 -7	4 10 -7	1 10 -6	5 10 -7	1 10 -6	3 10 -7	4 10 -7	2 10 -7
Ni	2 10 -8	3 10 -8	4 10 -8	3 10 -8	3 10 -8	4 10 -8	4 10 -8	3 10 -8	4 10 -8	3 10 -8	4 10 -8	4 10 -8	4 10 -8	4 10 -8	4 10 -8	4 10 -8	6 10 -8	8 10 -8	1 10 -7	4 10 -7	8 10 -8	1 10 -7	4 10 -8	6 10 -8	7 10 -8
Pb	9 10 -10	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	1 10 -9	2 10 -9	1 10 -9	3 10 -9	1 10 -9	1 10 -9	5 10 -10
Total CR	**3 10 -7**	**3 10 -7**	**3 10 -7**	**3 10 -7**	**3 10 -7**	**4 10 -7**	**4 10 -7**	**3 10 -7**	**4 10 -7**	**3 10 -7**	**3 10 -7**	**4 10 -7**	**4 10 -7**	**4 10 -7**	**4 10 -7**	**4 10 -7**	**5 10 -7**	**5 10 -7**	**6 10 -7**	**1 10 -6**	**6 10 -7**	**1 10 -6**	**4 10 -7**	**5 10 -7**	**3 10 -7**

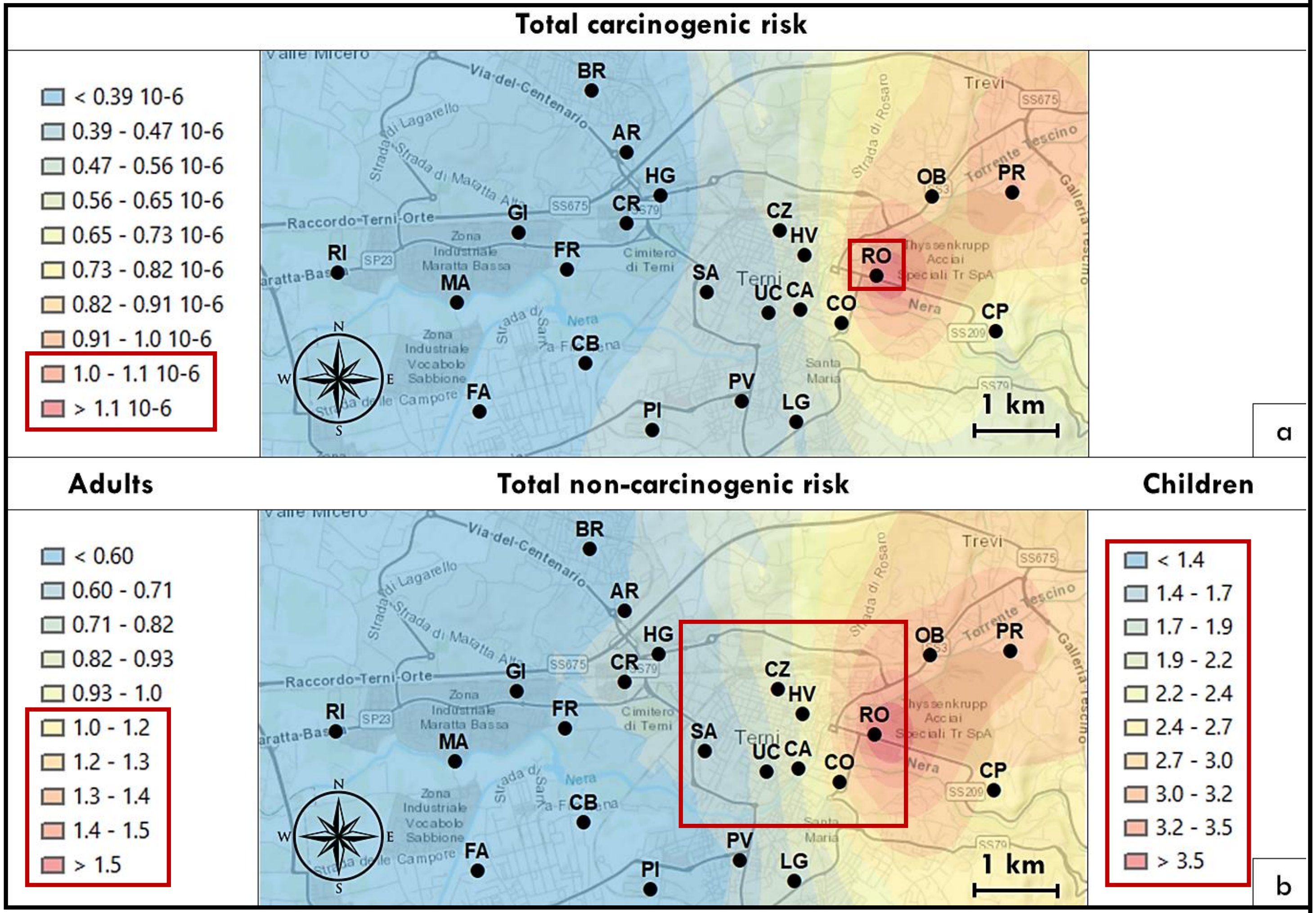
Non-carcinogenic risk - Adults

	RI	MA	FA	GI	FR	CB	PI	BR	AR	CR	HG	SA	PV	LG	CZ	HV	UC	CA	CO	RO	OB	PR	CP	AM	SD
Cd	1 10 -2	1 10 -2	2 10 -2	2 10 -2	2 10 -2	2 10 -2	2 10 -2	2 10 -2	2 10 -2	1 10 -2	2 10 -2	2 10 -2	2 10 -2	2 10 -2	1 10 -2	2 10 -2	2 10 -2	2 10 -2	2 10 -2	2 10 -2	2 10 -2	3 10 -2	2 10 -2	2 10 -2	3 10 -3
Co	3 10 -2	3 10 -2	4 10 -2	4 10 -2	3 10 -2	4 10 -2	4 10 -2	3 10 -2	3 10 -2	4 10 -2	4 10 -2	4 10 -2	4 10 -2	4 10 -2	4 10 -2	4 10 -2	6 10 -2	6 10 -2	7 10 -2	3 10 -1	6 10 -2	9 10 -2	4 10 -2	5 10 -2	5 10 -2
Cr	2 10 -1	2 10 -1	2 10 -1	2 10 -1	2 10 -1	2 10 -1	2 10 -1	2 10 -1	2 10 -1	2 10 -1	2 10 -1	2 10 -1	2 10 -1	2 10 -1	2 10 -1	3 10 -1	3 10 -1	4 10 -1	5 10 -1	2	4 10 -1	7 10 -1	3 10 -1	3 10 -1	3 10 -1
Cu	8 10 -5	9 10 -5	8 10 -5	1 10 -4	9 10 -5	6 10 -5	6 10 -5	7 10 -5	8 10 -5	1 10 -4	1 10 -4	8 10 -5	8 10 -5	7 10 -5	1 10 -4	7 10 -5	7 10 -5	1 10 -4	1 10 -4	9 10 -5	6 10 -5	8 10 -5	5 10 -5	9 10 -5	3 10 -5
Mn	2 10 -1	3 10 -1	3 10 -1	4 10 -1	3 10 -1	3 10 -1	2 10 -1	3 10 -1	3 10 -1	3 10 -1	3 10 -1	3 10 -1	3 10 -1	2 10 -1	3 10 -1	3 10 -1	3 10 -1	4 10 -1	4 10 -1	7 10 -1	4 10 -1	7 10 -1	3 10 -1	3 10 -1	1 10 -1
Ni	5 10 -4	6 10 -4	8 10 -4	7 10 -4	6 10 -4	9 10 -4	9 10 -4	7 10 -4	8 10 -4	7 10 -4	7 10 -4	8 10 -4	8 10 -4	8 10 -4	8 10 -4	8 10 -4	1 10 -3	2 10 -3	2 10 -3	8 10 -3	2 10 -3	2 10 -3	9 10 -4	1 10 -3	1 10 -3
Pb	3 10 -4	4 10 -4	5 10 -4	4 10 -4	4 10 -4	4 10 -4	4 10 -4	4 10 -4	4 10 -4	4 10 -4	4 10 -4	4 10 -4	4 10 -4	4 10 -4	4 10 -4	4 10 -4	4 10 -4	5 10 -4	5 10 -4	7 10 -4	5 10 -4	1 10 -3	5 10 -4	5 10 -4	2 10 -4
Sb	6 10 -3	8 10 -3	7 10 -3	9 10 -3	6 10 -3	5 10 -3	4 10 -3	5 10 -3	6 10 -3	8 10 -3	9 10 -3	6 10 -3	5 10 -3	4 10 -3	7 10 -3	5 10 -3	5 10 -3	7 10 -3	7 10 -3	5 10 -3	4 10 -3	5 10 -3	3 10 -3	6 10 -3	2 10 -3
Zn	5 10 -5	5 10 -5	8 10 -5	6 10 -5	5 10 -5	6 10 -5	6 10 -5	6 10 -5	6 10 -5	5 10 -5	7 10 -5	6 10 -5	6 10 -5	5 10 -5	6 10 -5	6 10 -5	6 10 -5	8 10 -5	6 10 -5	7 10 -5	6 10 -5	1 10 -4	6 10 -5	6 10 -5	1 10 -5
Total NCR	**4 10 -1**	**5 10 -1**	**6 10 -1**	**7 10 -1**	**6 10 -1**	**6 10 -1**	**5 10 -1**	**5 10 -1**	**6 10 -1**	**6 10 -1**	**7 10 -1**	**6 10 -1**	**6 10 -1**	**5 10 -1**	**6 10 -1**	**6 10 -1**	**7 10 -1**	**9 10 -1**	**9 10 -1**	**3**	**9 10 -1**	**2**	**6 10 -1**	**8 10 -1**	**5 10 -1**

Non-carcinogenic risk - Children

	RI	MA	FA	GI	FR	CB	PI	BR	AR	CR	HG	SA	PV	LG	CZ	HV	UC	CA	CO	RO	OB	PR	CP	AM	SD
Cd	3 10 -2	3 10 -2	5 10 -2	4 10 -2	4 10 -2	4 10 -2	4 10 -2	4 10 -2	4 10 -2	3 10 -2	4 10 -2	4 10 -2	4 10 -2	5 10 -2	3 10 -2	4 10 -2	4 10 -2	5 10 -2	4 10 -2	5 10 -2	4 10 -2	6 10 -2	4 10 -2	4 10 -2	8 10 -3
Co	6 10 -2	7 10 -2	9 10 -2	9 10 -2	8 10 -2	8 10 -2	8 10 -2	8 10 -2	8 10 -2	8 10 -2	9 10 -2	1 10 -1	9 10 -2	8 10 -2	9 10 -2	1 10 -1	1 10 -1	1 10 -1	2 10 -1	6 10 -1	1 10 -1	2 10 -1	9 10 -2	1 10 -1	1 10 -1
Cr	4 10 -1	4 10 -1	5 10 -1	6 10 -1	5 10 -1	5 10 -1	5 10 -1	5 10 -1	5 10 -1	6 10 -1	6 10 -1	6 10 -1	6 10 -1	5 10 -1	5 10 -1	6 10 -1	7 10 -1	1	1	4	1	2	7 10 -1	8 10 -1	7 10 -1
Cu	2 10 -3	2 10 -3	2 10 -3	3 10 -3	2 10 -3	1 10 -3	1 10 -3	2 10 -3	2 10 -3	3 10 -3	3 10 -3	2 10 -3	2 10 -3	2 10 -3	3 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	1 10 -3	2 10 -3	6 10 -4
Mn	5 10 -1	7 10 -1	7 10 -1	9 10 -1	7 10 -1	6 10 -1	6 10 -1	6 10 -1	7 10 -1	8 10 -1	8 10 -1	7 10 -1	6 10 -1	6 10 -1	8 10 -1	7 10 -1	7 10 -1	8 10 -1	8 10 -1	2	8 10 -1	2	7 10 -1	8 10 -1	3 10 -1
Ni	1 10 -3	1 10 -3	2 10 -3	2 10 -3	1 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	2 10 -3	3 10 -3	4 10 -3	5 10 -3	2 10 -2	4 10 -3	5 10 -3	2 10 -3	3 10 -3	3 10 -3
Pb	8 10 -4	9 10 -4	1 10 -3	1 10 -3	1 10 -3	1 10 -3	9 10 -4	1 10 -3	1 10 -3	9 10 -4	9 10 -4	1 10 -3	1 10 -3	1 10 -3	1 10 -3	1 10 -3	1 10 -3	1 10 -3	1 10 -3	2 10 -3	1 10 -3	3 10 -3	1 10 -3	1 10 -3	5 10 -4
Sb	1 10 -2	2 10 -2	2 10 -2	2 10 -2	1 10 -2	1 10 -2	1 10 -2	1 10 -2	1 10 -2	2 10 -2	2 10 -2	1 10 -2	1 10 -2	1 10 -2	2 10 -2	1 10 -2	1 10 -2	2 10 -2	2 10 -2	1 10 -2	9 10 -3	1 10 -2	7 10 -3	1 10 -2	4 10 -3
Zn	1 10 -4	1 10 -4	2 10 -4	1 10 -4	1 10 -4	1 10 -4	1 10 -4	1 10 -4	1 10 -4	1 10 -4	2 10 -4	1 10 -4	1 10 -4	1 10 -4	1 10 -4	1 10 -4	1 10 -4	2 10 -4	1 10 -4	2 10 -4	1 10 -4	3 10 -4	1 10 -4	1 10 -4	3 10 -5
Total NCR	**1**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**6**	**2**	**4**	**1**	**2**	**1**

Values higher than 1 × 10^{-6} for CR and than 1 for NCR indicate a higher risk associated with exposure to PTTEs in PM_{10}



Positive Matrix Factorization (PMF)

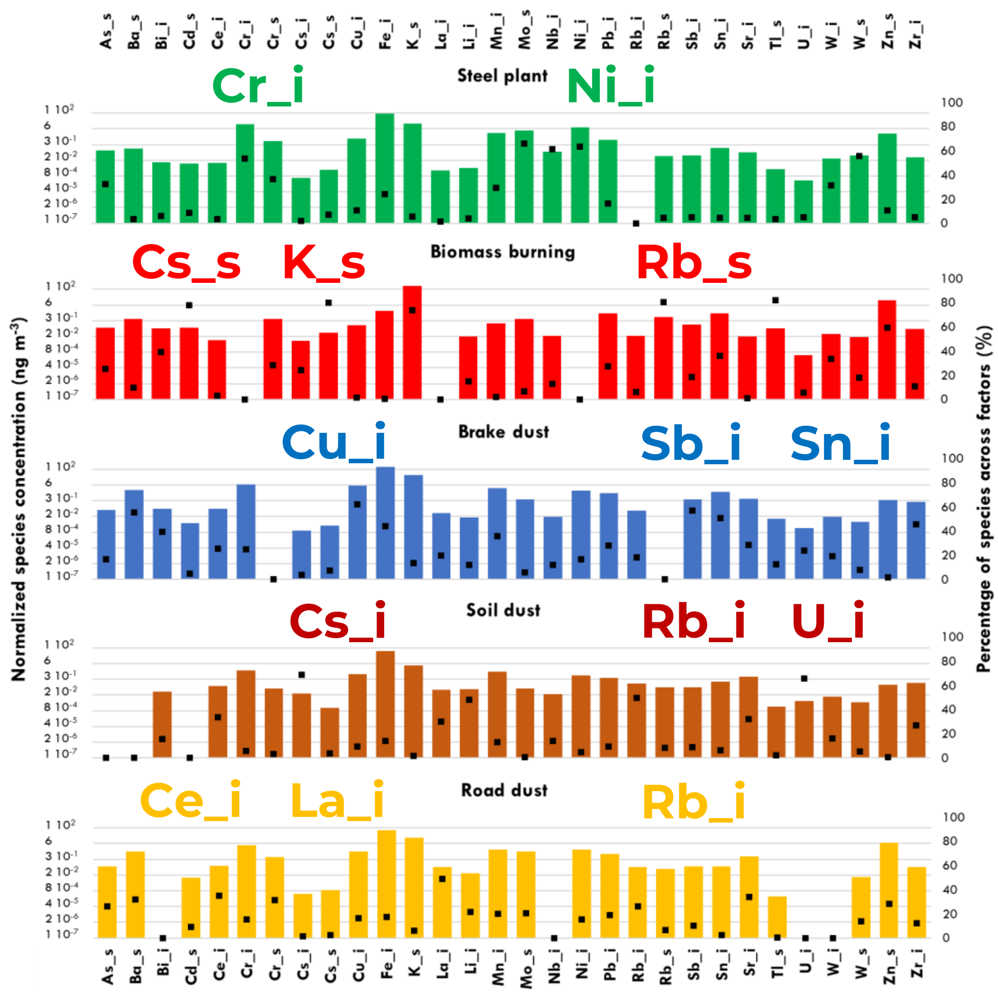
A receptor modelling (RM) approach based on PMF to identify sources acting at the 23 sites and apportion the total CR and NCR of PTTEs in PM_{10} to source-specific risk contributions:

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

where x_{ij} is the measured mass fraction of species j in sample i,g_{ik} is the mass contribution of the source k to sample i, f_{kj} is the fractional abundance of the species j in source k and e_{ij} is the residual between the measured and modelled mass fraction of species.

Taghvaee, S., Sowlat, M. H., Hassanvand, M. S., Yunesian, M., Naddafi, K., Sioutas, C. 2018. Source-specific lung cancer risk assessment of ambient PM2. 5-bound polycyclic aromatic hydrocarbons (PAHs) in central Tehran. Environment international, 120, 321-332. DOI: 10.1016/j.envint.2018.08.003

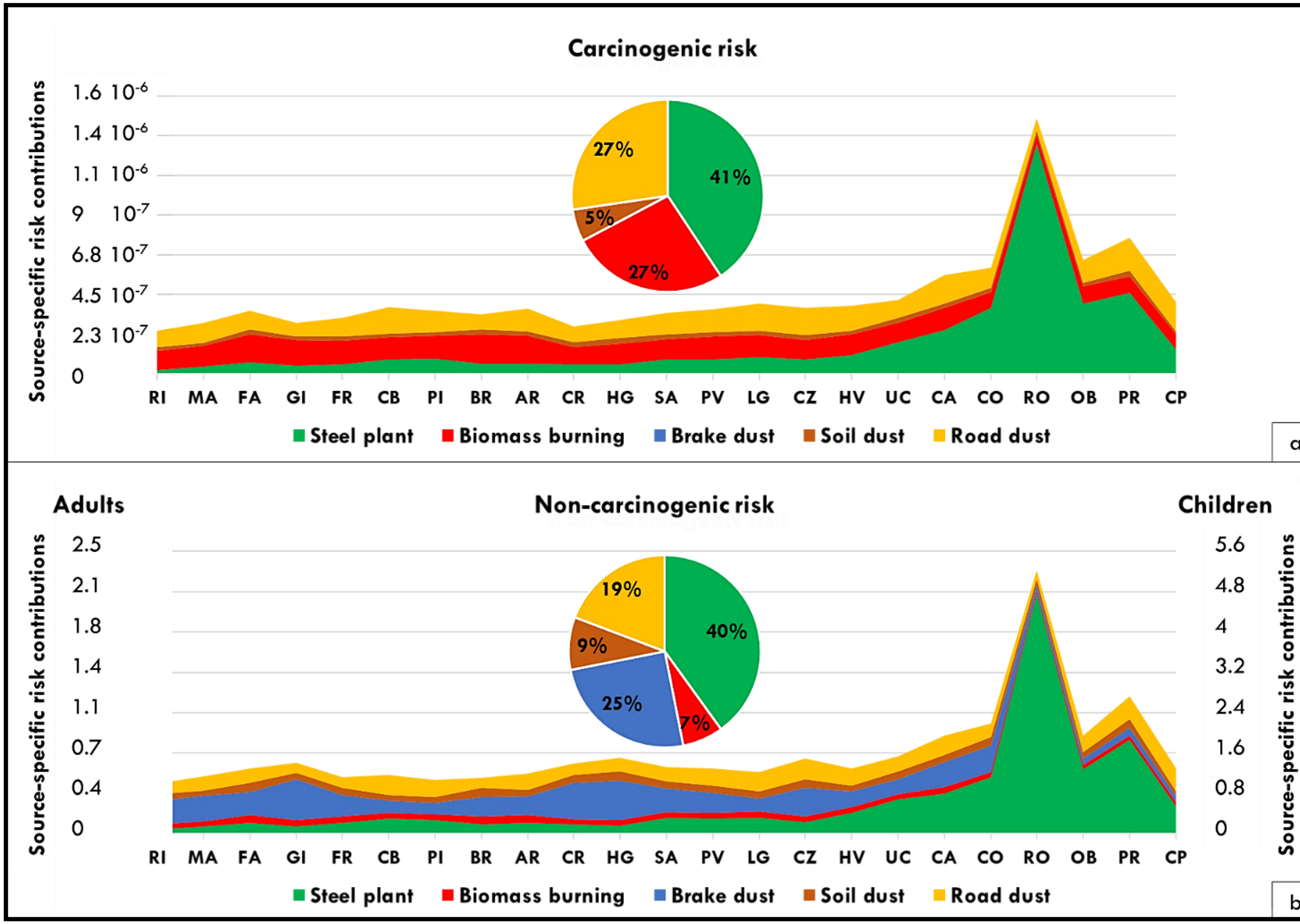
The most stable PMF solution extracts 5 factors: steel plant, biomass burning, brake dust, soil dust, road dust



The innovative use of spatially- instead of time-resolved concentrations in the PMF analysis allowed us to trace very-robust elemental profiles reducing the bias due to atmospheric stability conditions

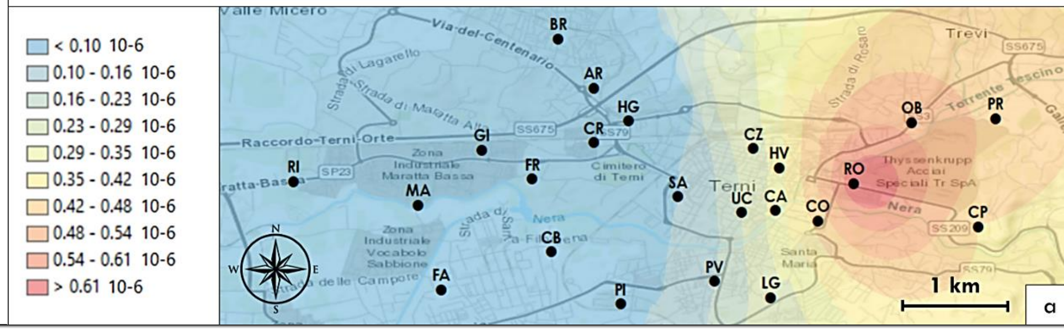
Greatest contribution to total CR and NCR from the steel plant

Total NCR for children significant in the entire study area



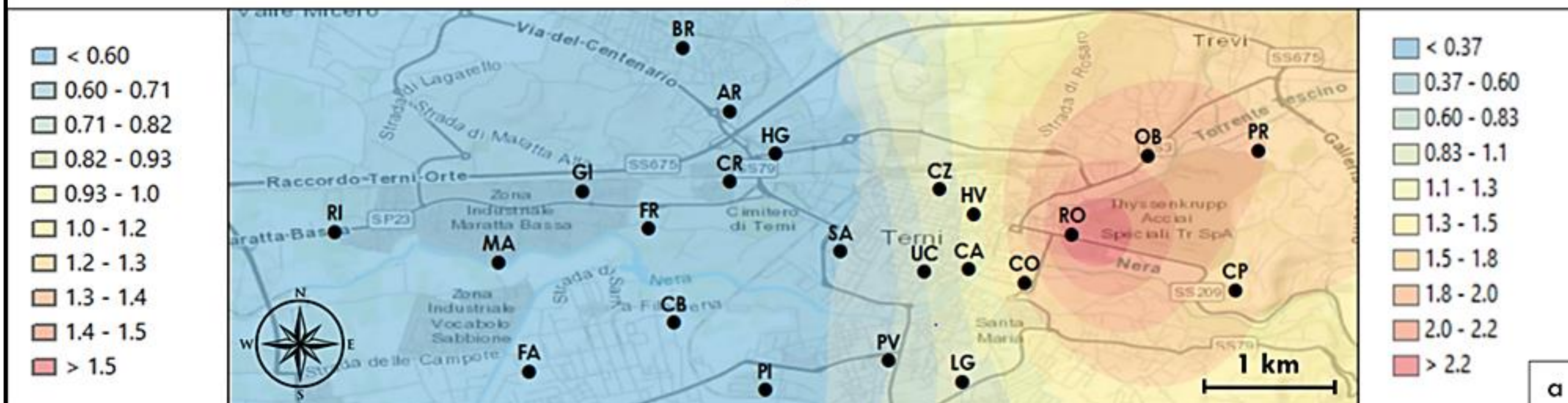
Carcinogenic risk

Steel plant



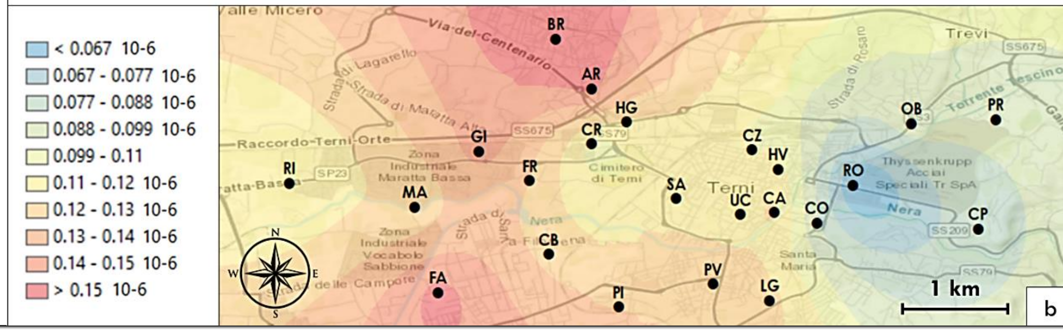
Adults **Non-carcinogenic risk** **Children**

Steel plant



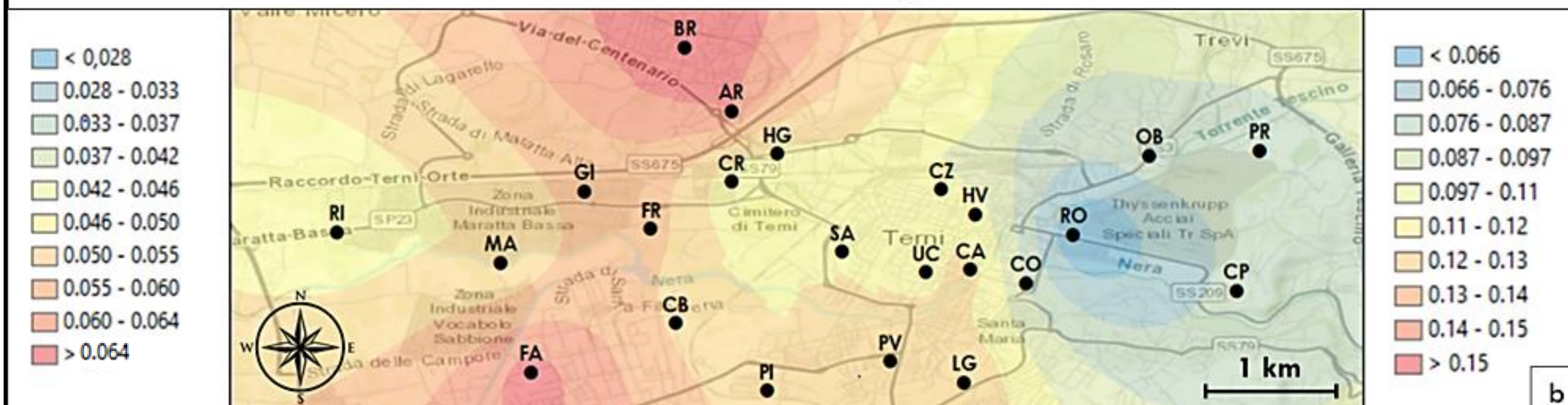
Carcinogenic risk

Biomass burning



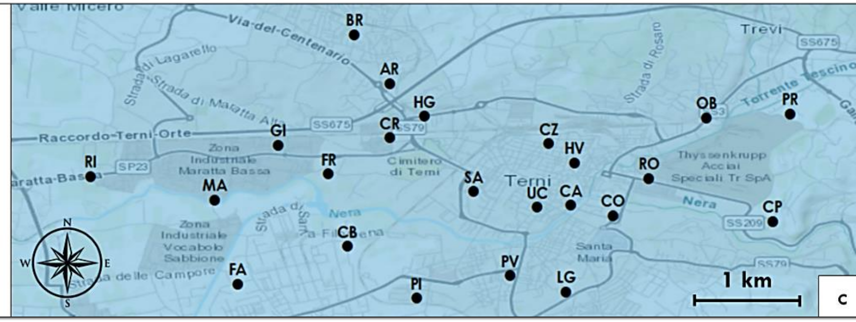
Adults **Non-carcinogenic risk** **Children**

Biomass burning



Carcinogenic risk
Brake dust

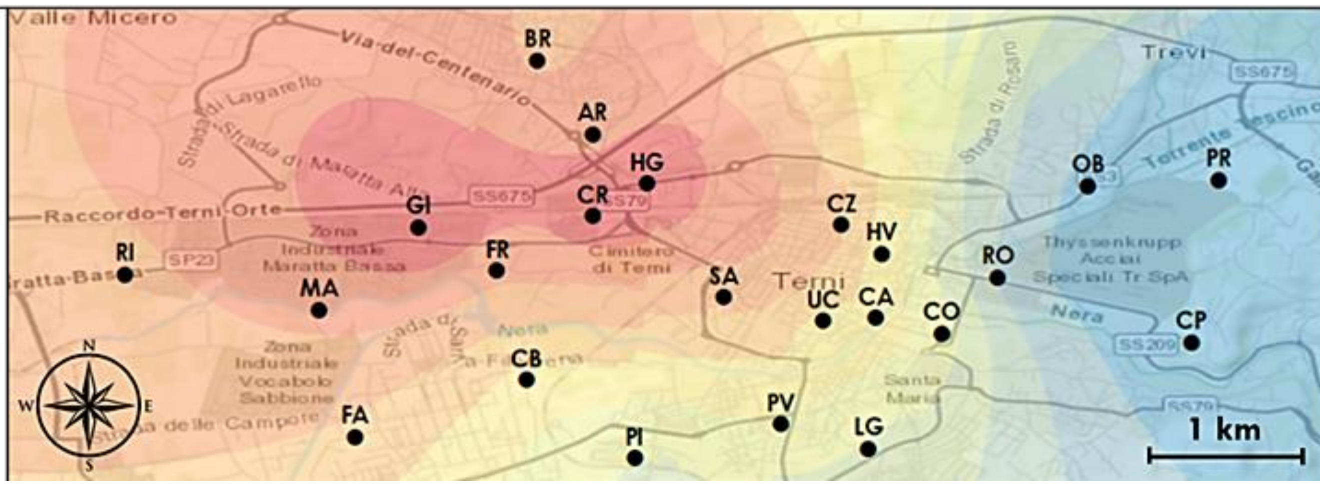
0



c

Adults	Non-carcinogenic risk	Children
	Brake dust	

<0.084
0.084 - 0.10
0.10 - 0.12
0.12 - 0.14
0.14 - 0.16
0.16 - 0.18
0.18 - 0.20
0.20 - 0.22
0.22 - 0.23
> 0.23



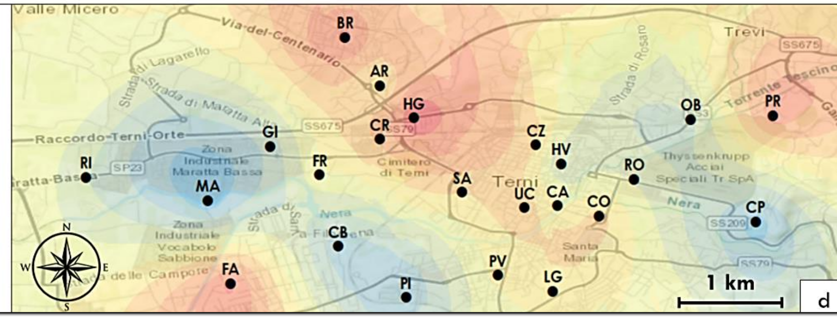
0.20
0.20 - 0.24
0.24 - 0.28
0.28 - 0.33
0.33 - 0.37
0.37 - 0.41
0.41 - 0.46
0.46 - 0.50
0.50 - 0.54
> 0.54

c

Carcinogenic risk

Soil dust

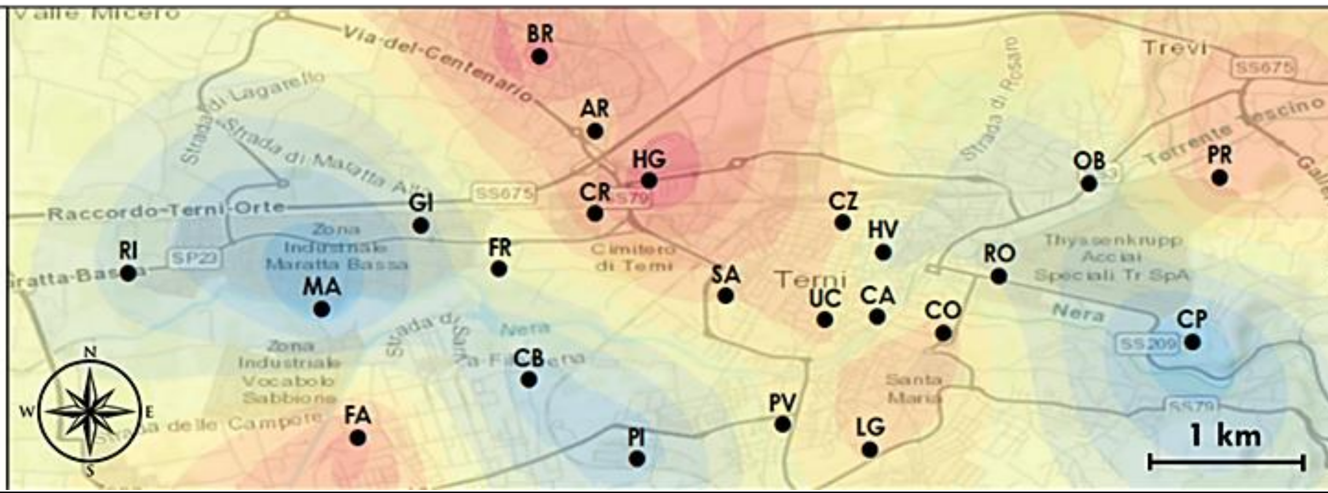
- < 0.020 10-6
- 0.020 - 0.021 10-6
- 0.021 - 0.022 10-6
- 0.022 - 0.023 10-6
- 0.023 - 0.024 10-6
- 0.024 - 0.025 10-6
- 0.025 - 0.027 10-6
- 0.027- 0.028 10-6
- 0.028 - 0.030 10-6
- > 0.030 10-6



Adults	**Non-carcinogenic risk**	**Children**

Soil dust

Adults:
- < 0.054
- 0.054 - 0.056
- 0.056 - 0.058
- 0.058 - 0.060
- 0.060 - 0.062
- 0.062 - 0.064
- 0.064 - 0.066
- 0.066 - 0.068
- 0.068- 0.070
- > 0.070



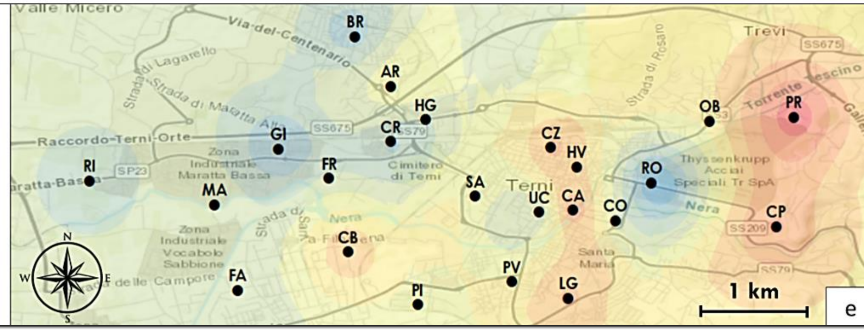
Children:
- < 0.12
- < 0.131
- 0.131 - 0.136
- 0.136 - 0.141
- 0.141 - 0.146
- 0.146 - 0.151
- 0.151 - 0.155
- 0.155 - 0.160
- 0.160 - 0.170
- > 0.170

d

Carcinogenic risk

Road dust

- < 0.079 10-6
- 0.079 - 0.091 10-6
- 0.091- 0.10 10-6
- 0.10 - 0.11 10-6
- 0.11 - 0.13 10-6
- 0.13 - 0.14 10-6
- 0.14 - 0.15 10-6
- 0.15 - 0.16 10-6
- 0.16 - 0.17 10-6
- > 0.17 10-6

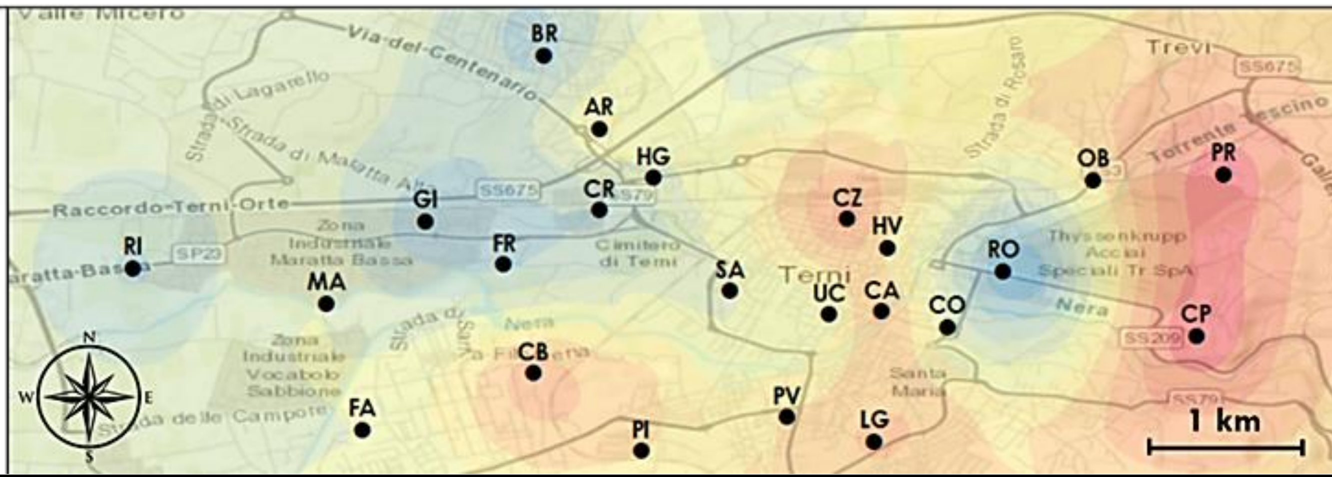


Adults | **Non-carcinogenic risk** | **Children**

Road dust

Adults:

- < 0.085
- 0.085 - 0.098
- 0.098 - 0.11
- 0.11 - 0.12
- 0.12 - 0.14
- 0.14 - 0.15
- 0.15 - 0.16
- 0.16 - 0.18
- 0.18 - 0.20
- > 0.20



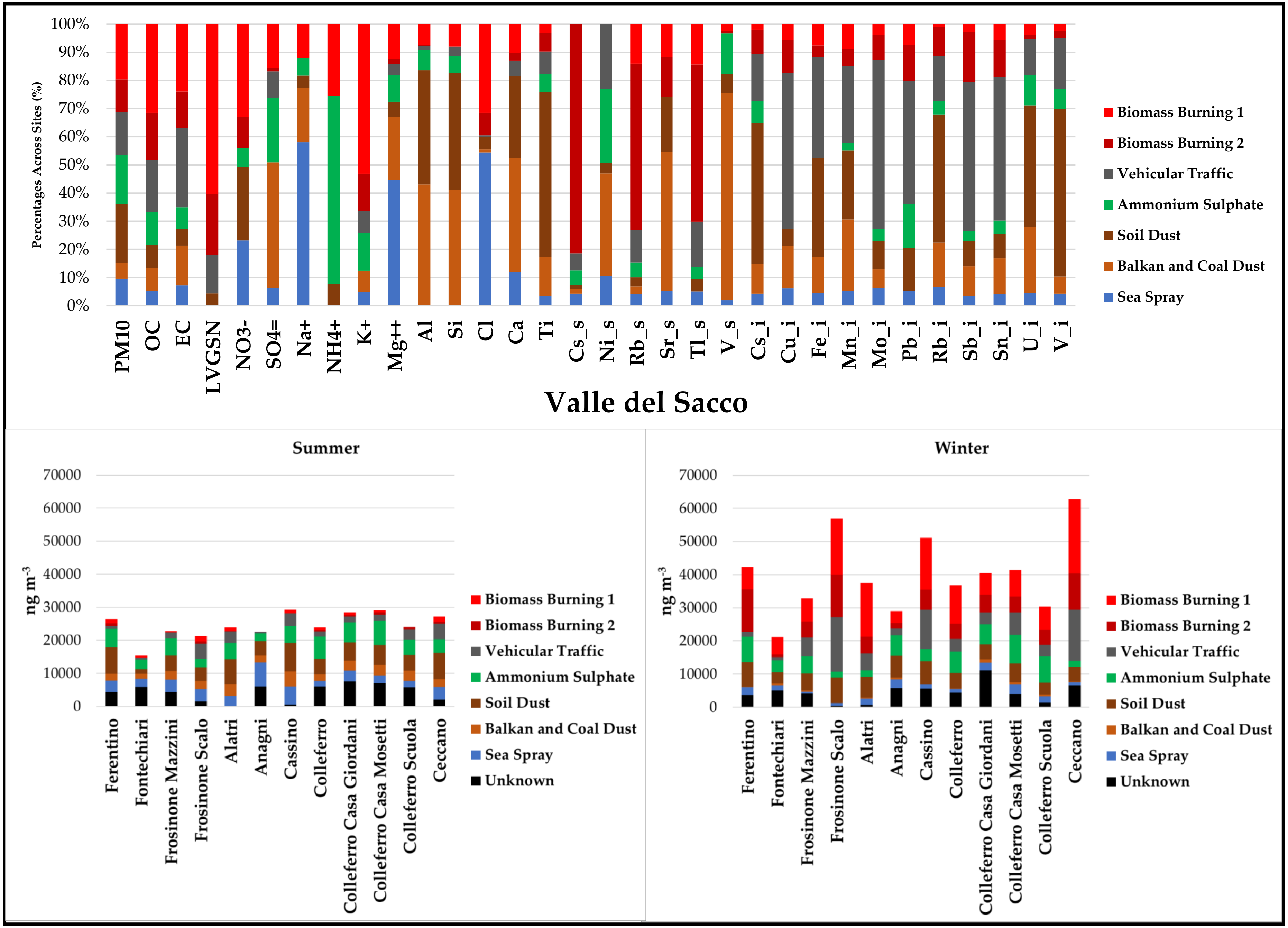
Children:

- < 0.20
- 0.20 - 0.23
- 0.23 - 0.26
- 0.26 - 0.29
- 0.29 - 0.32
- 0.32 - 0.35
- 0.35 - 0.38
- 0.38 - 0.41
- 0.41 - 0.44
- > 0.44

e

This innovative experimental approach is a powerful tool to localize the health risks of PTTEs in PM_{10} in urban settings polluted by multiple sources and it allows to assess the improvement in air quality that would occur by or reducing the contribution of one or more specific emission sources

Massimi, L., Pietrantonio, E., Astolfi, M. L., Canepari, S. 2022. Innovative experimental approach for spatial mapping of source-specific risk contributions of potentially toxic trace elements in PM10. Chemosphere, 307, 135871. DOI: 10.1016/j.chemosphere.2022.135871



Valle del Sacco
Percentages Across Sites (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
PM10
OC
EC
LVGSN
NO3-
SO4=
Na+
NH4+
K+
Mg++
Al
Si
Cl
Ca
Ti
Cs_s
Ni_s
Rb_s
Sr_s
Tl_s
V_s
Cs_i
Cu_i
Fe_i
Mn_i
Mo_i
Pb_i
Rb_i
Sb_i
Sn_i
U_i
V_i
Biomass Burning 1
Biomass Burning 2
Vehicular Traffic
Ammonium Sulphate
Soil Dust
Balkan and Coal Dust
Sea Spray
Summer
ng m-3
70000
60000
50000
40000
30000
20000
10000
0
Ferentino
Fontechiari
Frosinone Mazzini
Frosinone Scalo
Alatri
Anagni
Cassino
Colleferro
Colleferro Casa Giordani
Colleferro Casa Mosetti
Colleferro Scuola
Ceccano
Biomass Burning 1
Biomass Burning 2
Vehicular Traffic
Ammonium Sulphate
Soil Dust
Balkan and Coal Dust
Sea Spray
Unknown
Winter
ng m-3
70000
60000
50000
40000
30000
20000
10000
0
Ferentino
Fontechiari
Frosinone Mazzini
Frosinone Scalo
Alatri
Anagni
Cassino
Colleferro
Colleferro Casa Giordani
Colleferro Casa Mosetti
Colleferro Scuola
Ceccano
Biomass Burning 1
Biomass Burning 2
Vehicular Traffic
Ammonium Sulphate
Soil Dust
Balkan and Coal Dust
Sea Spray
Unknown

GIORNATE DI STUDIO

LA CARATTERIZZAZIONE CHIMICA DEL PARTICOLATO ATMOSFERICO

V EDIZIONE

Terni, 21-22 Novembre 2022

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