JOINT INSTITUTE FOR NUCLEAR RESEARCH
Frank Laboratory of Neutron Physics

VŠB – TECHNICAL UNIVERSITY OF OSTRAVA
Faculty of Mining and Geology
Institute of Environmental Engineering

DETERMINATION OF THE AIR POLLUTION SOURCES BY MOSS BIOMONITORING IN THE UPPER SILESIA REGION

Krakovská Aneta, Svozilík Vladislav, Jančík Petr

Biomonitoring

- Using organism or biological materials to get information about the environment
- Unusual behaviour or concentration of substances in tissues or/and meshes

Why biomonitoring?

- Not expensive sampling devices
- Concentration in organism is higher then concentration in the environment -> higher accuracy
- Substances in organism reflect long-term concentrations (not influenced by local extremes)
- Fast and easy sampling

Why mosses?

- Surface of their above-ground parts is in good contact with the atmospheric air, moss cuticles enable penetration of ions into cells
- Underdeveloped root system -> intake of substances from soil is insignificant
- Mosses are usually tolerant even to a high pollution level
- Some types of moss (*Hylocomium splendens*, *Pleurozium schreberi*, *Hypnum cupressiforme*) frequently occur in a wide range
- Exposure period is easy to determine (3-year-growth segments of mosses are usually taken for analysis)

ICP Vegetation

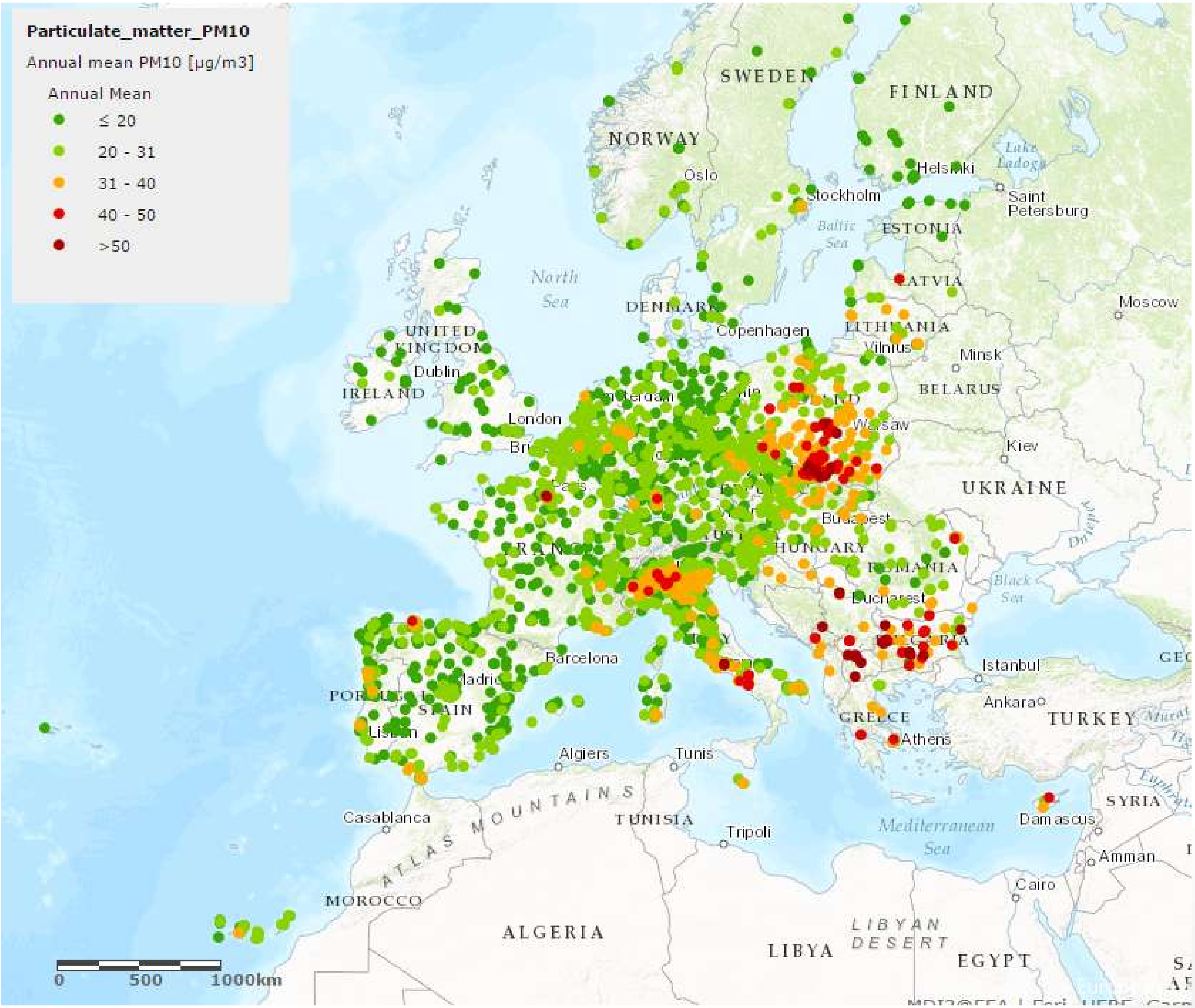
CEH Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

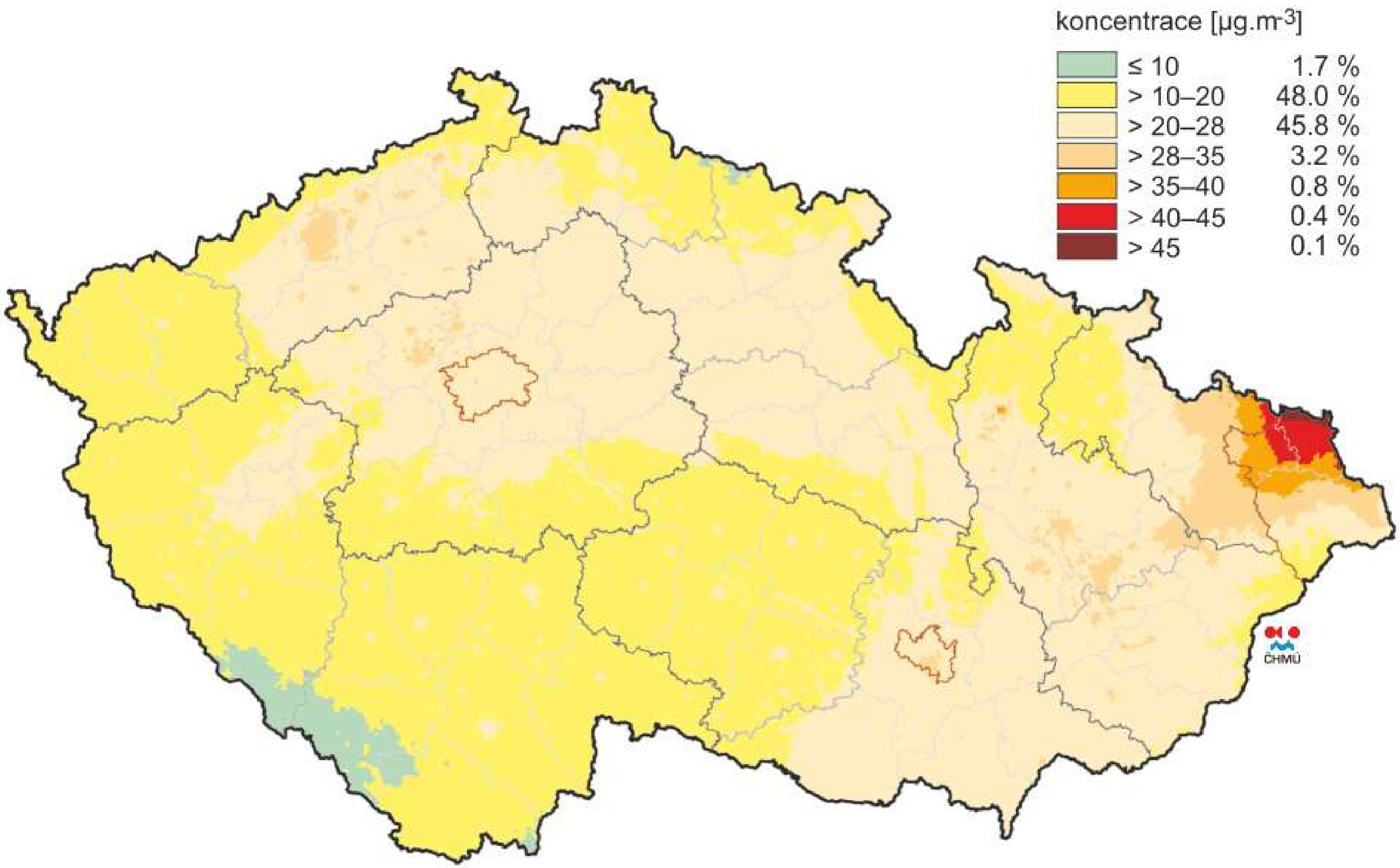
- The ICP Vegetation is an international research program investigating the impacts of air pollutants on crops and (semi-)natural vegetation.
- It reports to the Working Group on Effects (WGE) of the UNECE Convention on Long-Range Transboundary Air Pollution.
- The program focuses on
  - the impacts of ozone pollution on vegetation
  - the atmospheric deposition of heavy metals, nitrogen and persistent organic pollutants (POPs) to vegetation.

- The program is led by the UK, has its Program Coordination Centre at the Centre for Ecology and Hydrology.
- Coordination of the program is mainly funded by the UK Department for Environment Food and Rural Affairs.

wge
Working Group on Effects
of the
Convention on Long-range Transboundary Air Pollution

Methods

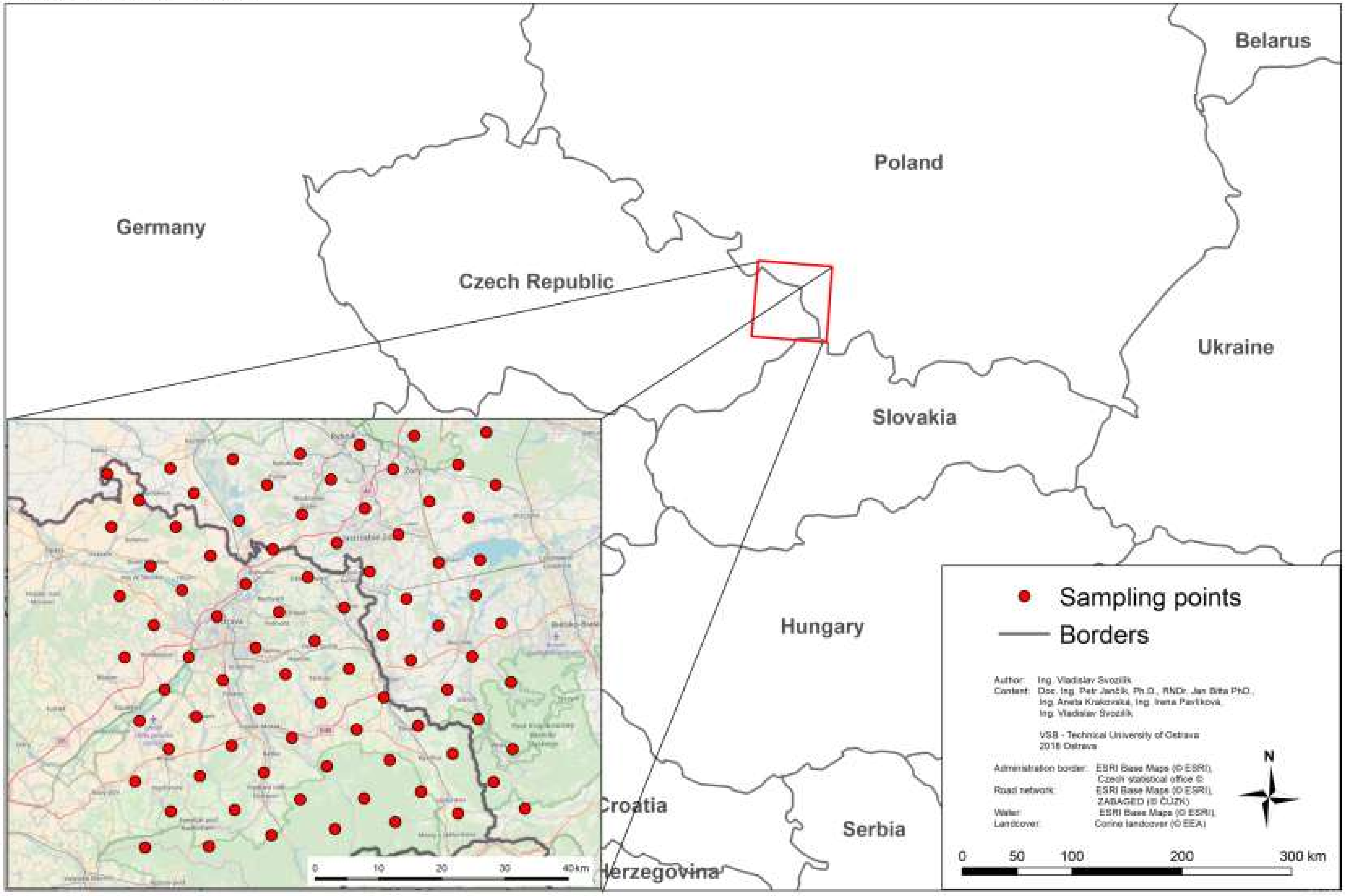

Particulate_matter_PM10
Annual mean PM10 [µg/m3]
Annual Mean
≤ 20
20 - 31
31 - 40
40 - 50
>50
0
500
1000km



Obr. IV.1.9 Pětiletý průměr ročních průměrných koncentrací PM_{10}, 2011–2015

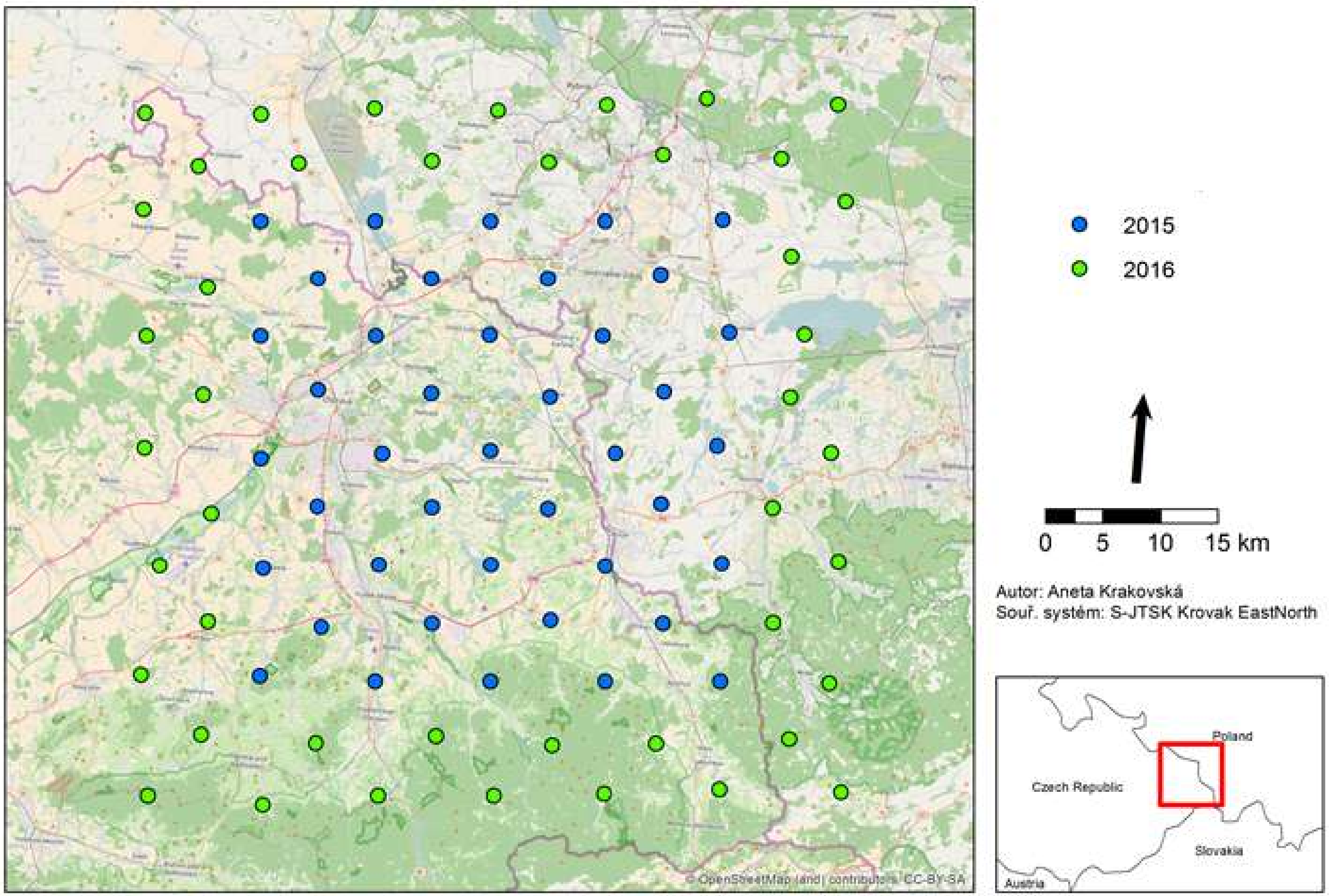
5-years annual mean of concentration PM10, 2011-2015

SAMPLING AREA



Methods

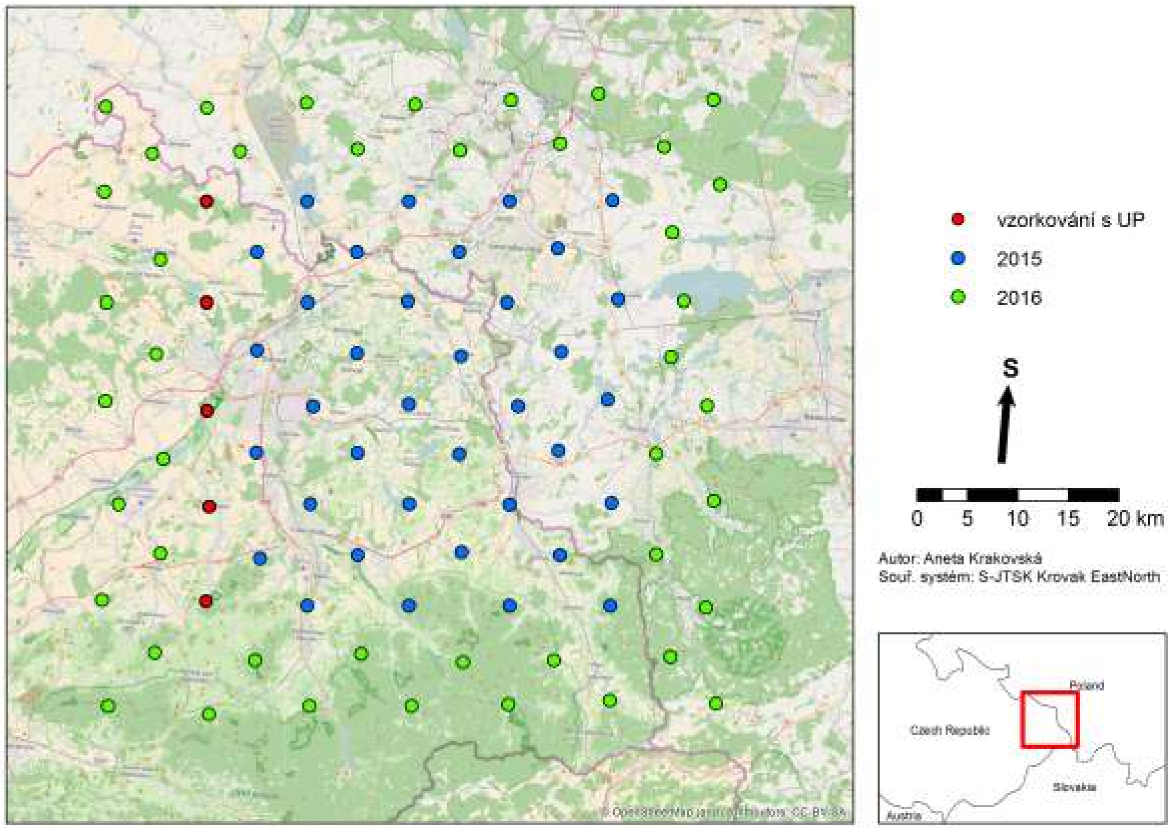
- Creation of a point network using GIS technology (41 locations – 40 x 40 km^2)
- Expansion of the network (+ 44 locations)



Methods

Přírodovědecká fakulta

- In 2017, soil and Isopods (*Porcellio scaber, Oniscus asellus)* sampling in co-operation with the Palacký University Olomouc



Methods - Sample processing

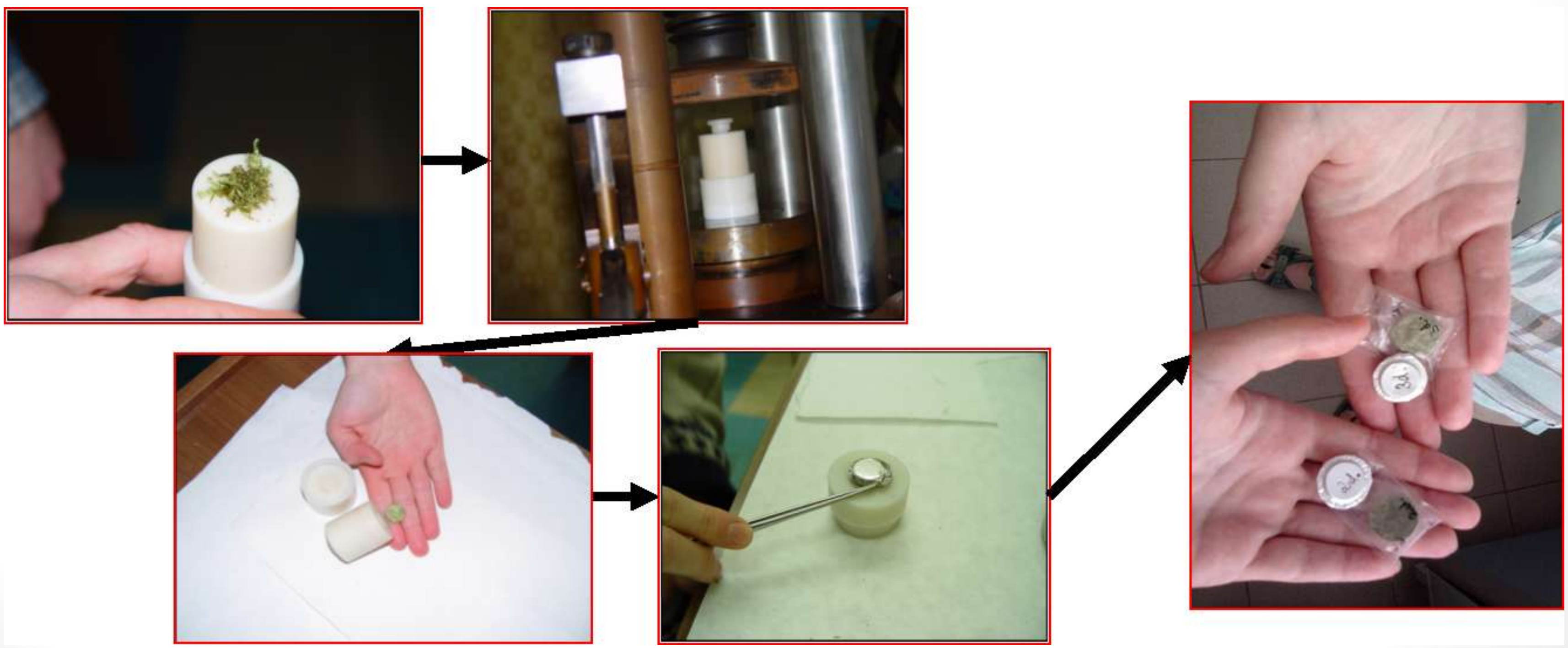
HEAVY METALS, NITROGEN AND POPs IN EUROPEAN MOSSES: 2015 SURVEY

MONITORING MANUAL

International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops

Methods - Sample processing

- Frank Laboratory of Neutron Physics - Joint Institute for Nuclear Research
  - Department of Neutron Activation Analysis



Methods – Sample analysis

- Analysis of the samples using neutron activation analysis (NAA) at the IBR-2 reactor of the FLNP

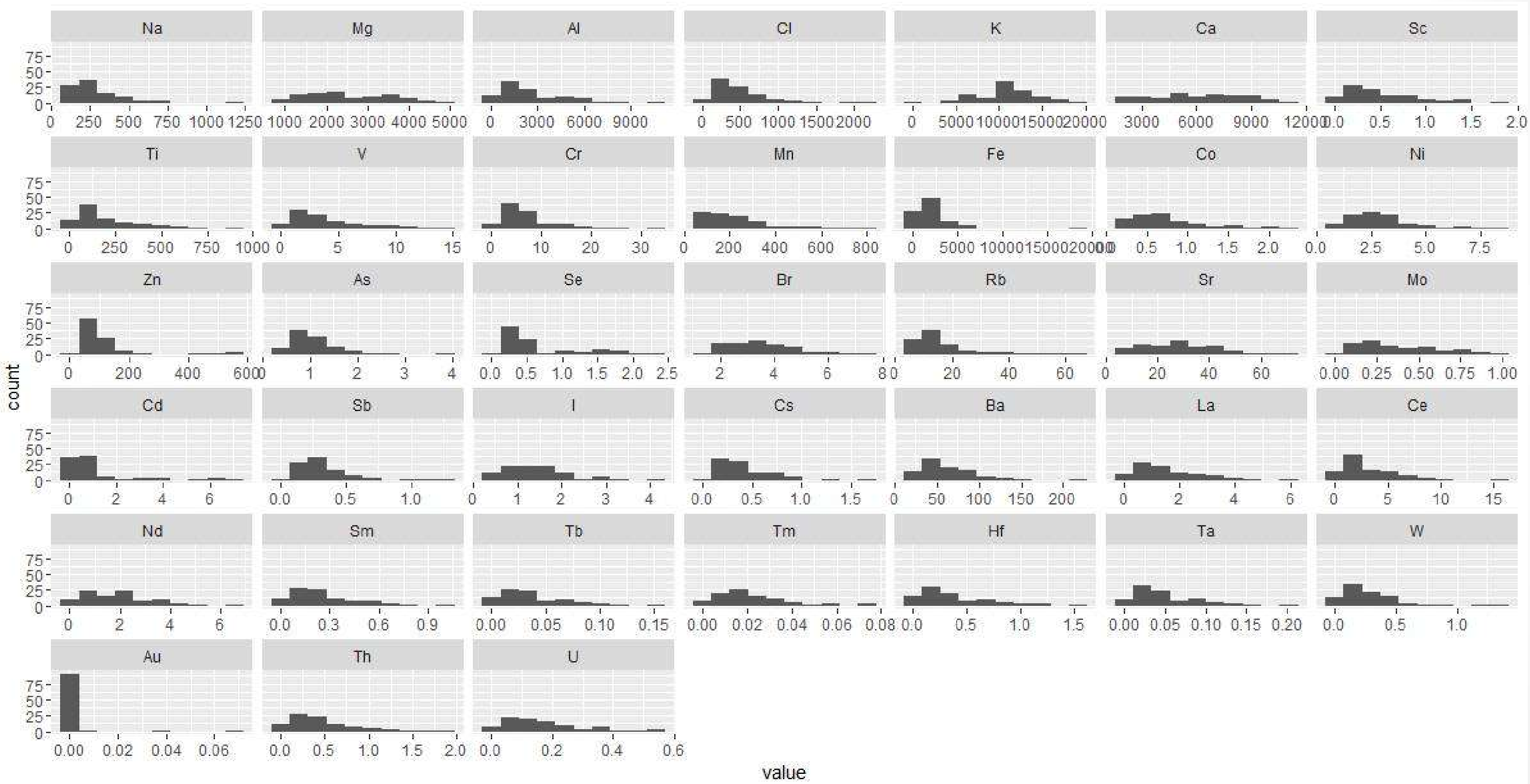
Results

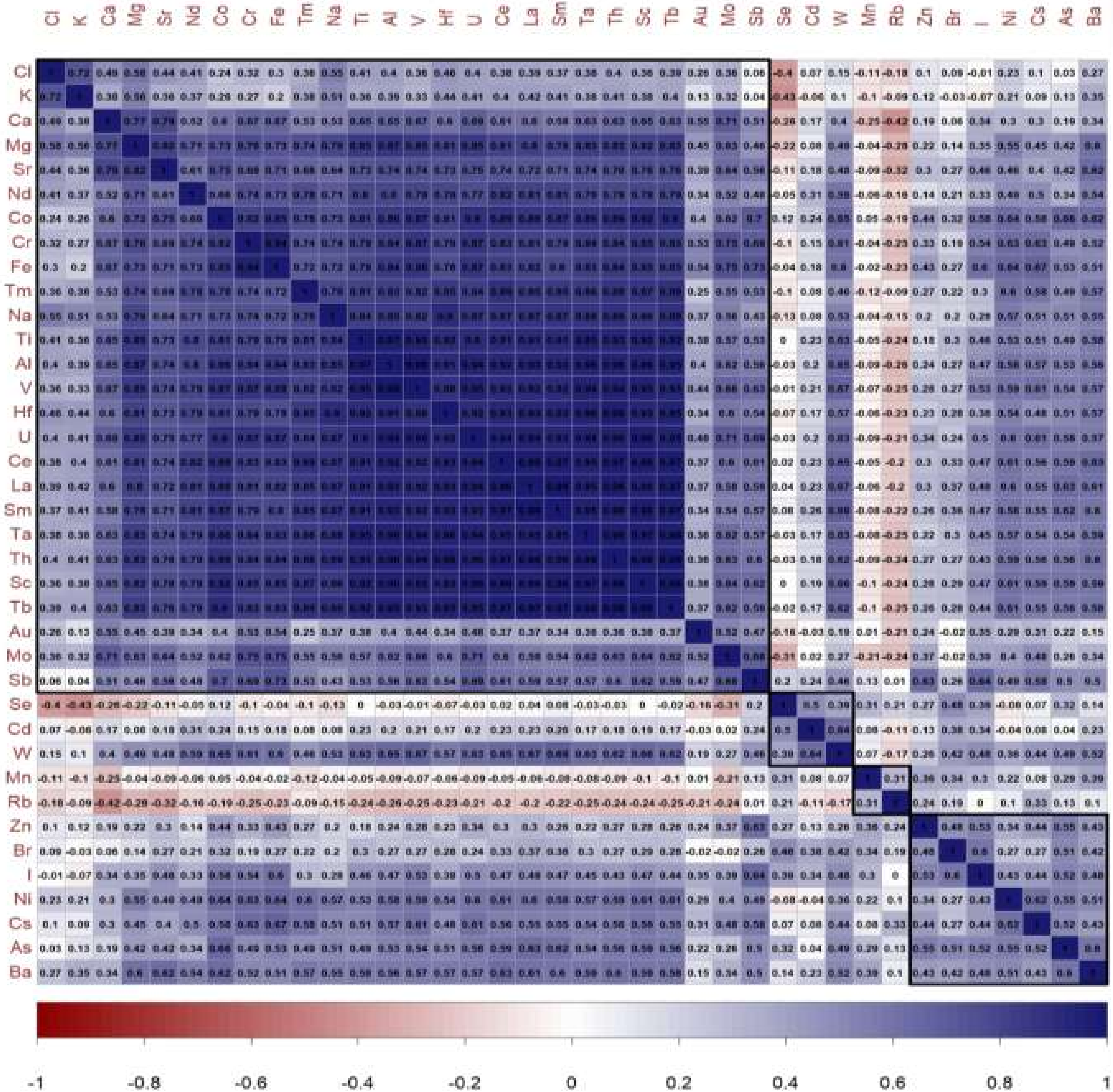
- 37 elements
- Na Mg Al Cl K Ca Sc Ti V Cr Mn Fe Co Ni Zn As Se Br Rb Sr Mo Cd Sb I Cs Ba La Ce Nd Sm Tb Tm Hf Ta W Au Th U

	Na	Mg	Al	Cl	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Zn	As	Se	Br	Rb
nbr.val	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94
min	84.9	789	305	69.3	1040	1540	0.0532	22.3	0.551	1.1	45.7	338	0.119	0.711	30.6	0.286	0.0601	1.65	5.94
max	1150	4790	11000	2240	20200	10600	1.86	923	14.9	34.1	767	18700	2.13	8.26	587	3.75	2.39	7.73	63.8
range	1065.1	4001	10695	2170.7	19160	9060	1.8068	900.7	14.349	33	721.3	18362	2.011	7.549	556.4	3.464	2.3299	6.08	57.86
sum	25881.8	237717	237086	47403.2	1026260	561760	47.4737	18893.3	375.054	643.31	21411.8	207563	71.476	278.811	10563	100.41	59.6761	332.97	1606.46
median	222	2355	1820	391	11100	6010	0.411	135.5	2.865	5.475	193.5	1715	0.6425	2.67	86.1	0.965	0.394	3.275	13.3
mean	275.3383	2528.904	2522.191	504.2894	10917.66	5976.17	0.505039	200.9926	3.989936	6.843723	227.7851	2208.117	0.760383	2.966074	112.3723	1.068191	0.634852	3.542234	17.09
SE.mean	17.75986	103.5224	217.4682	40.41765	335.6677	249.8121	0.039434	18.1225	0.320965	0.570782	15.76798	231.7241	0.049561	0.151215	11.02241	0.053178	0.05516	0.134525	1.180209
CI.mean.0.95	35.26757	205.575	431.8487	80.26144	666.5695	496.0772	0.078307	35.98769	0.637372	1.133459	31.31208	460.1581	0.098417	0.300283	21.88833	0.105601	0.109537	0.267139	2.34366
var	29648.8	1007388	4445487	153557.1	10591242	5866170	0.146171	30871.95	9.683722	30.62441	23371.14	5047428	0.230888	2.149401	11420.4	0.265821	0.286005	1.701106	130.9319
std.dev	172.1883	1003.687	2108.432	391.8637	3254.419	2422.018	0.382324	175.7042	3.111868	5.533932	152.8762	2246.648	0.480508	1.466084	106.8663	0.515578	0.534794	1.304264	11.44255
coef.var	0.62537	0.396886	0.835953	0.777061	0.298088	0.405279	0.757018	0.874182	0.779929	0.808614	0.671142	1.01745	0.631928	0.494284	0.951002	0.482665	0.842392	0.368204	0.669546

Sr	Mo	Cd	Sb	I	Cs	Ba	La	Ce	Nd	Sm	Tb	Tm	Hf	Ta	W	Au	Th	U
94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94
5.65	0.0158	0.02	0.049	0.349	0.0784	13.1	0.194	0.011	0.249	0.0264	0.00348	0.00151	0.0248	0.00404	0.0301	0.00003	0.049	0.0209
69.2	1	7.09	1.31	4.08	1.74	209	6.13	15.6	6.82	1.03	0.156	0.0752	1.56	0.206	1.38	0.0683	1.92	0.562
63.55	0.9842	7.07	1.261	3.731	1.6616	195.9	5.936	15.589	6.571	1.0036	0.15252	0.07369	1.5352	0.20196	1.3499	0.06827	1.871	0.5411
2590.17	36.6217	110.6559	31.5845	132.315	38.608	5918.5	150.15	302.264	179.2015	24.489	3.58022	2.10711	36.0735	4.77469	25.5659	0.168834	45.9402	16.8656
26.65	0.3425	0.575	0.279	1.315	0.325	54.9	1.205	2.345	1.805	0.2015	0.02865	0.0177	0.27	0.0367	0.2265	0.000453	0.363	0.1405
27.555	0.389593	1.17719	0.336005	1.407606	0.410723	62.96277	1.59734	3.215574	1.906399	0.260521	0.038087	0.022416	0.383761	0.050795	0.271978	0.001796	0.488726	0.179421
1.378407	0.025292	0.176307	0.023208	0.074299	0.028933	3.474421	0.124364	0.275535	0.136754	0.020615	0.003121	0.001702	0.034865	0.004242	0.023887	0.000808	0.041028	0.014341
2.737243	0.050225	0.350111	0.046087	0.147542	0.057455	6.899512	0.246962	0.547158	0.271567	0.040938	0.006197	0.00338	0.069236	0.008425	0.047435	0.001605	0.081474	0.028478
178.6005	0.06013	2.921922	0.05063	0.518906	0.078689	1134.731	1.453834	7.136447	1.757966	0.03995	0.000915	0.000272	0.114265	0.001692	0.053635	6.14E-05	0.158233	0.019332
13.36415	0.245214	1.709363	0.225011	0.720352	0.280516	33.68576	1.20575	2.671413	1.325883	0.199874	0.030256	0.016504	0.338031	0.041132	0.231593	0.007838	0.397785	0.139038
0.484999	0.629412	1.45207	0.669665	0.511756	0.682981	0.535011	0.754849	0.830773	0.695491	0.767207	0.79437	0.736273	0.880839	0.809777	0.851513	4.364045	0.813924	0.774924

Results –statistical distribution





Al – V

Al – Sc

V – Ni

Th – U

Al – Th

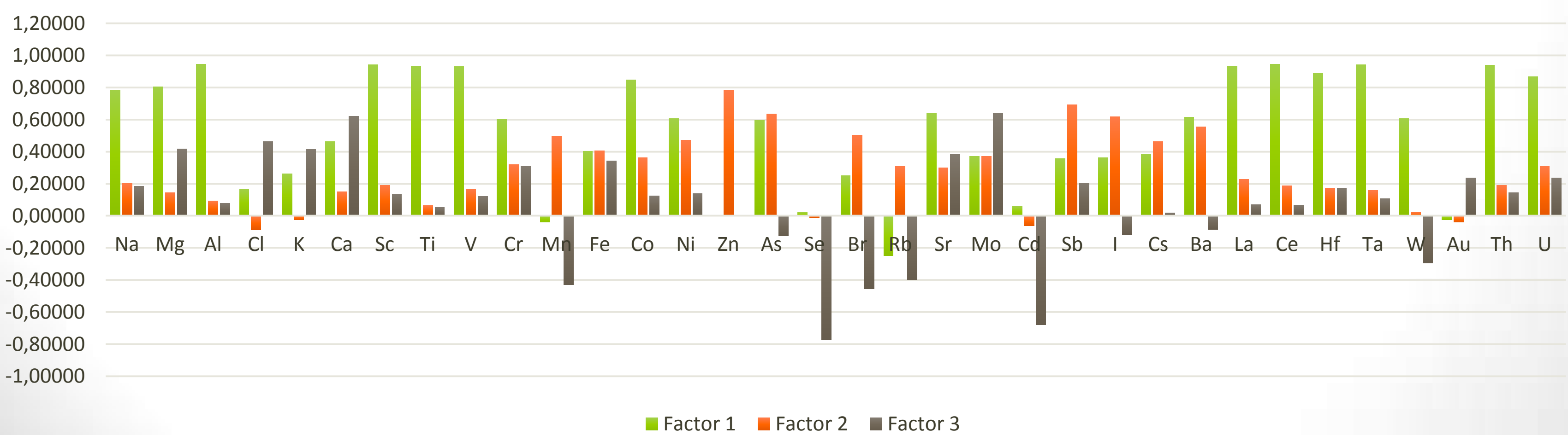
Fe – Co

Fe – Cr

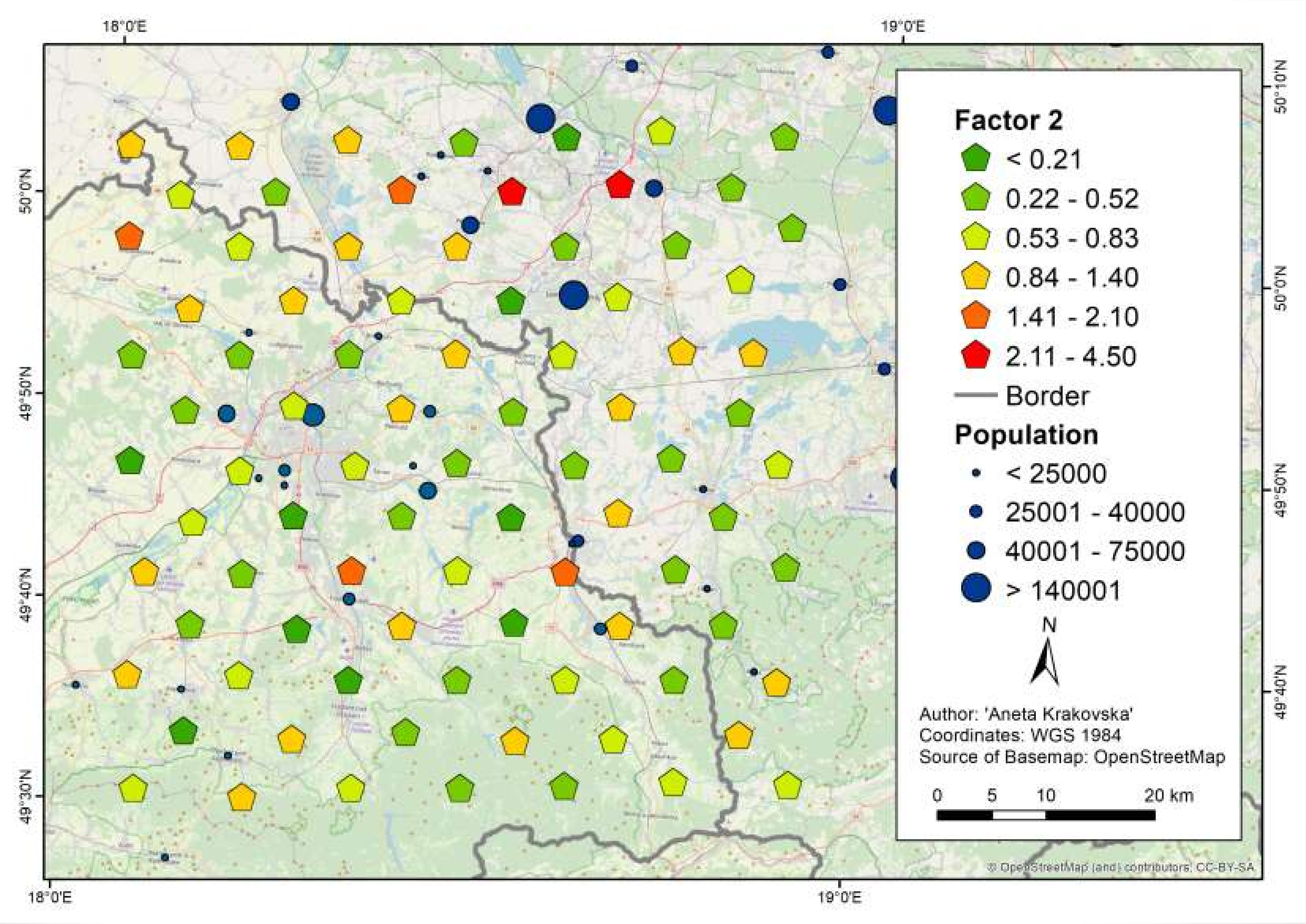
Factor analysis

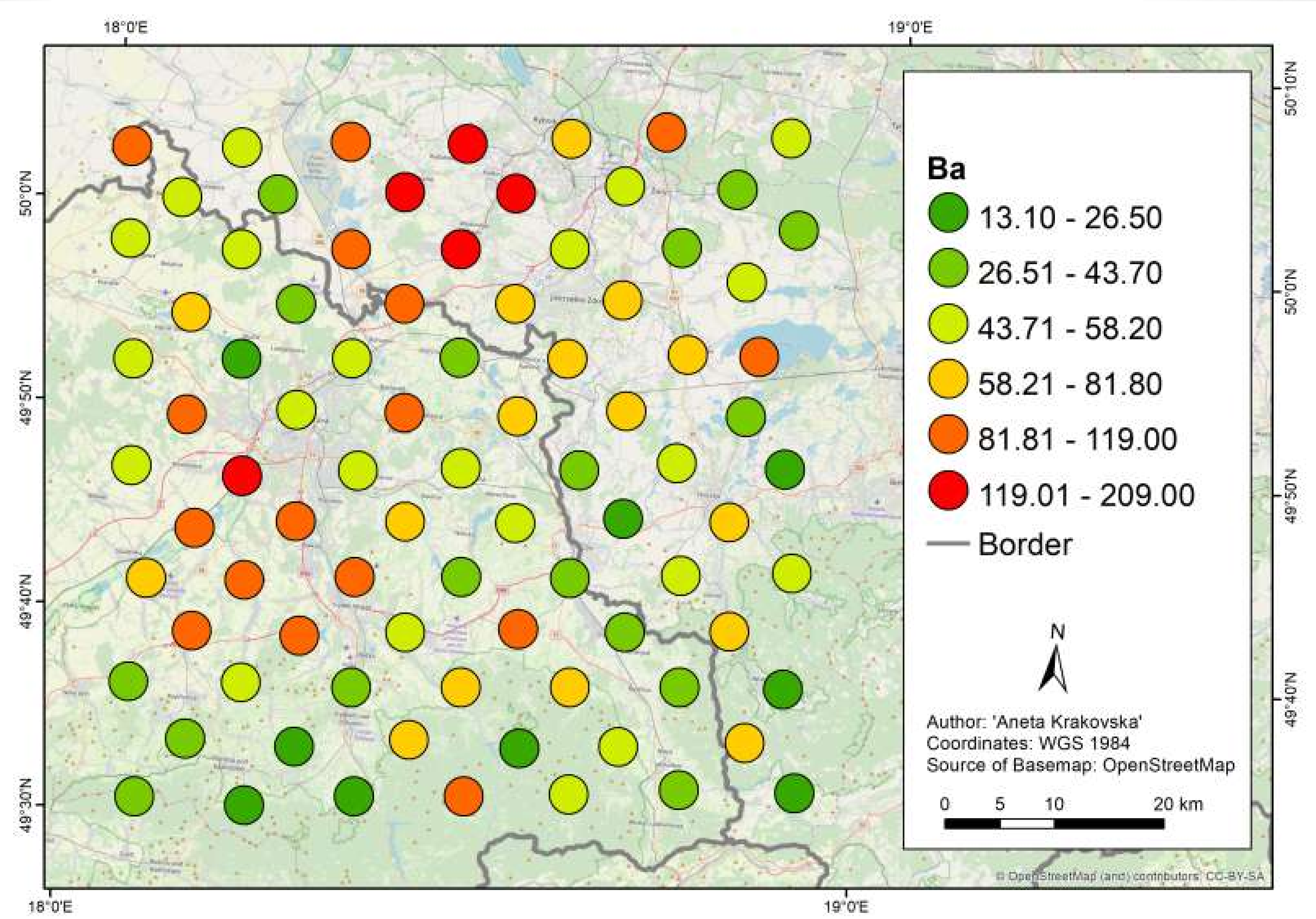
- Factor 1 (Na, Mg, Al, Sc, Ti, V, Cr, Co, Ni, As, Sr, Ba, La, Ce, Hf, Ta, W, Th, U)
- Factor 2 (Zn, As, Br, Sb, I, Ba).
  - The most significant samples which have influenced factor 2 are situated around mining cities with many power plants and above the underground brines in Poland.
- Factor 3 (Ca, Se, Mo, Cd).
  - Assumption of vegetation origin
  - All these samples are situated in unpolluted localities, even in a nature reserve.

	Factor 1	Factor 2	Factor 3
Na	0,78295	0,201391	0,184021
Mg	0,80460	0,145833	0,417336
Al	0,94596	0,092988	0,079848
Cl	0,16621	-0,086948	0,462524
K	0,26107	-0,024169	0,415412
Ca	0,46198	0,150880	0,621344
Sc	0,94335	0,191389	0,135967
Ti	0,93232	0,062687	0,051577
V	0,93008	0,164758	0,120904
Cr	0,60206	0,319671	0,307601
Mn	-0,03890	0,496152	-0,430440
Fe	0,40316	0,405442	0,341698
Co	0,84695	0,361677	0,124910
Ni	0,60710	0,471893	0,139145
Zn	-0,00003	0,782548	-0,002184
As	0,59544	0,633844	-0,123875
Se	0,02092	-0,009478	-0,773275
Br	0,24988	0,503871	-0,454242
Rb	-0,24939	0,307864	-0,398546
Sr	0,63777	0,298343	0,382373
Mo	0,36979	0,370214	0,637271
Cd	0,05795	-0,063520	-0,677771
Sb	0,35724	0,691578	0,202502
I	0,36142	0,617481	-0,115462
Cs	0,38681	0,462963	0,017684
Ba	0,61522	0,554761	-0,085768
La	0,93339	0,227831	0,070945
Ce	0,94385	0,187333	0,067291
Hf	0,88898	0,174548	0,171719
Ta	0,94328	0,158359	0,106723
W	0,60697	0,019906	-0,295620
Au	-0,02531	-0,040490	0,237669
Th	0,93869	0,191497	0,144675
U	0,86867	0,309402	0,235497
Expl.Var	13,96080	4,286956	3,777247
Prp.Totl	0,41061	0,126087	0,111096

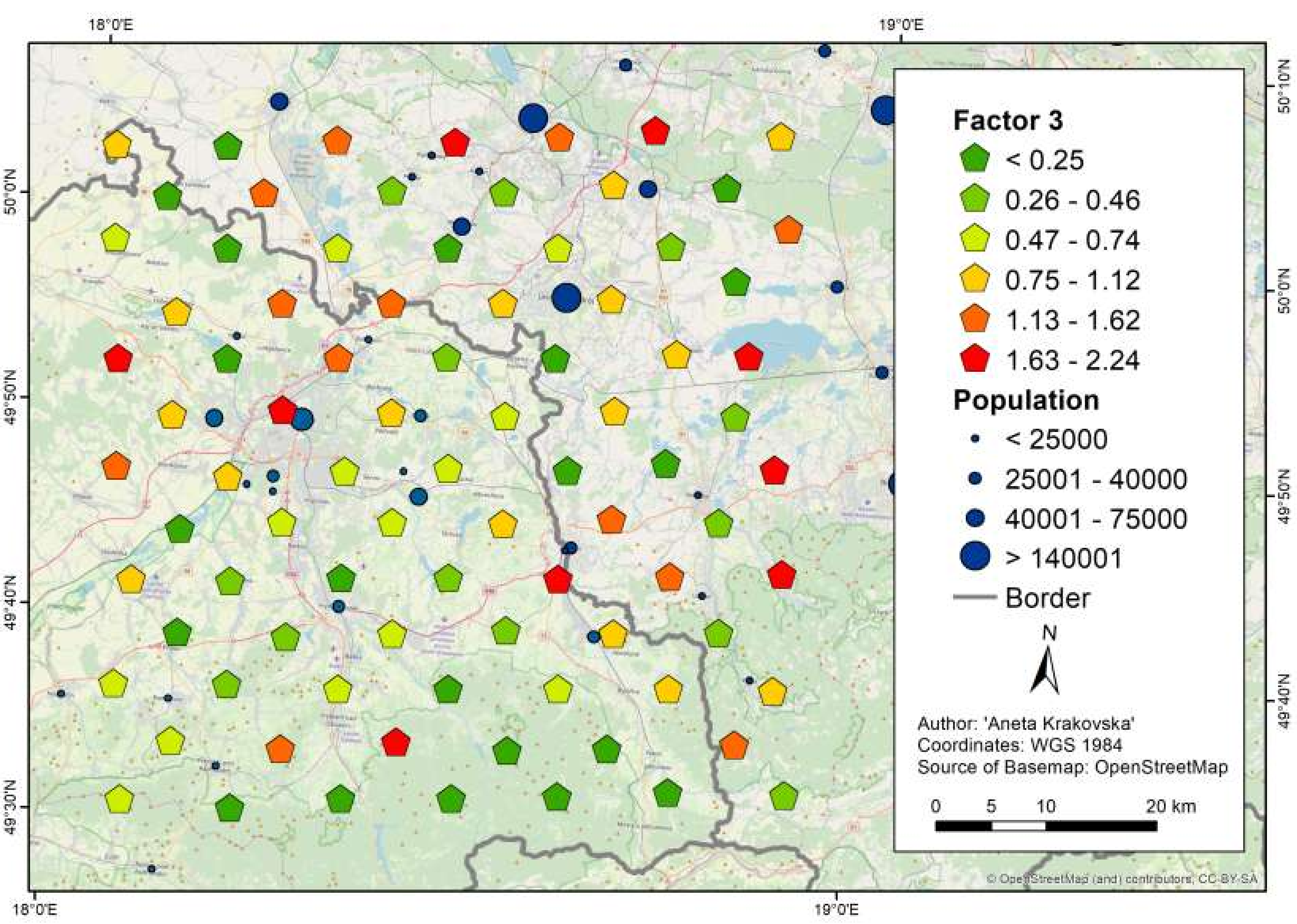


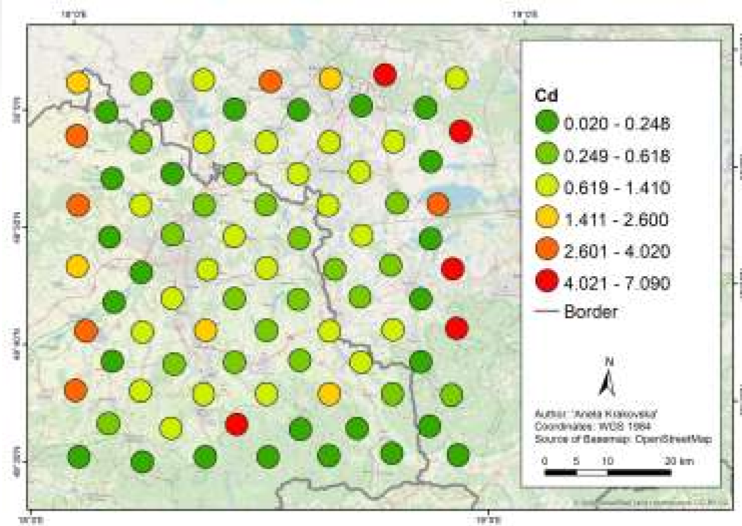
Factor 2 (Zn, As, Br, Sb, I, Ba)

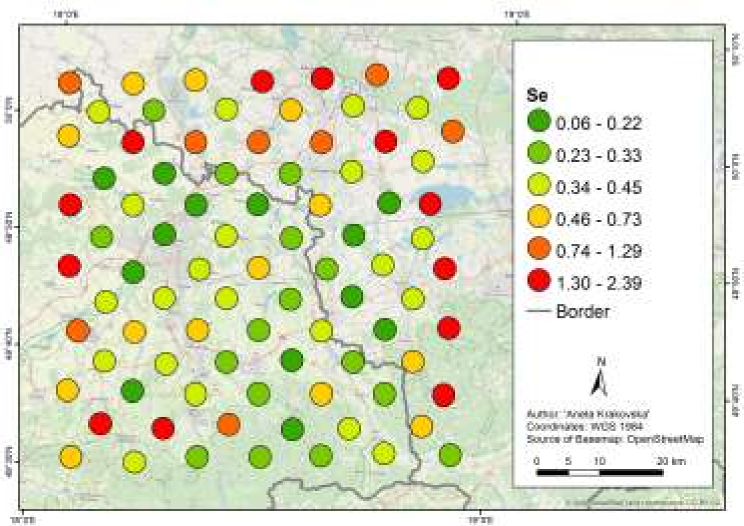


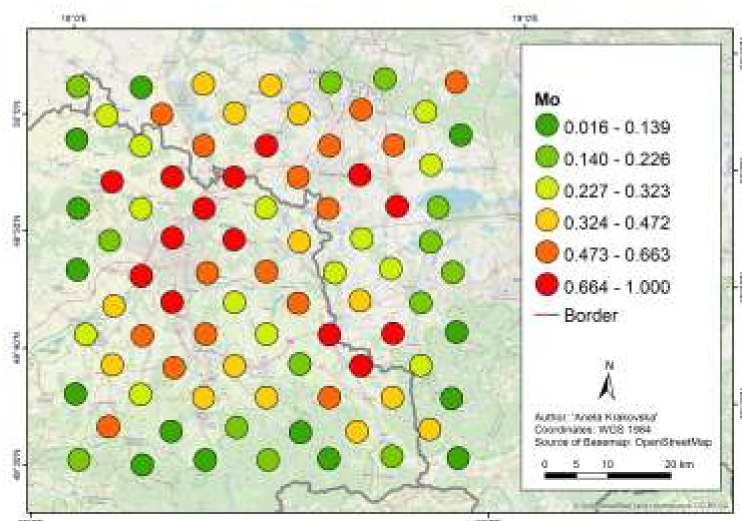

18°0'E
19°0'E
50°10'N
50°0'N
49°50'N
49°40'N
49°30'N
Ba
13.10 - 26.50
26.51 - 43.70
43.71 - 58.20
58.21 - 81.80
81.81 - 119.00
119.01 - 209.00
Border
N
Author: 'Aneta Krakovska'
Coordinates: WGS 1984
Source of Basemap: OpenStreetMap
0 5 10 20 km
© OpenStreetMap (and) contributors, CC-BY-SA

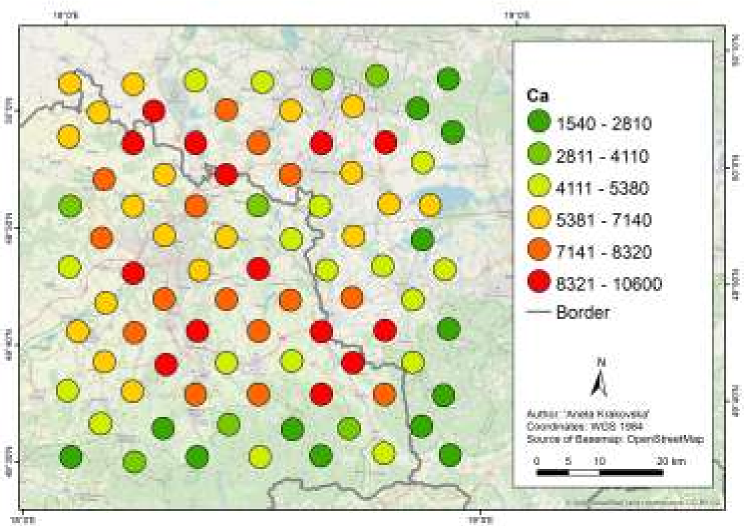
Factor 3 (Ca, Se, Mo, Cd)




Cd
0.020 - 0.248
0.249 - 0.618
0.619 - 1.410
1.411 - 2.600
2.601 - 4.020
4.021 - 7.090
Border
N


Se
0.06 - 0.22
0.23 - 0.33
0.34 - 0.45
0.46 - 0.73
0.74 - 1.29
1.30 - 2.39
Border
N


Mo
0.016 - 0.139
0.140 - 0.226
0.227 - 0.323
0.324 - 0.472
0.473 - 0.663
0.664 - 1.000
Border
N


Ca
1540 - 2810
2811 - 4110
4111 - 5380
5381 - 7140
7141 - 8320
8321 - 10600
Border
N

Contamination factor

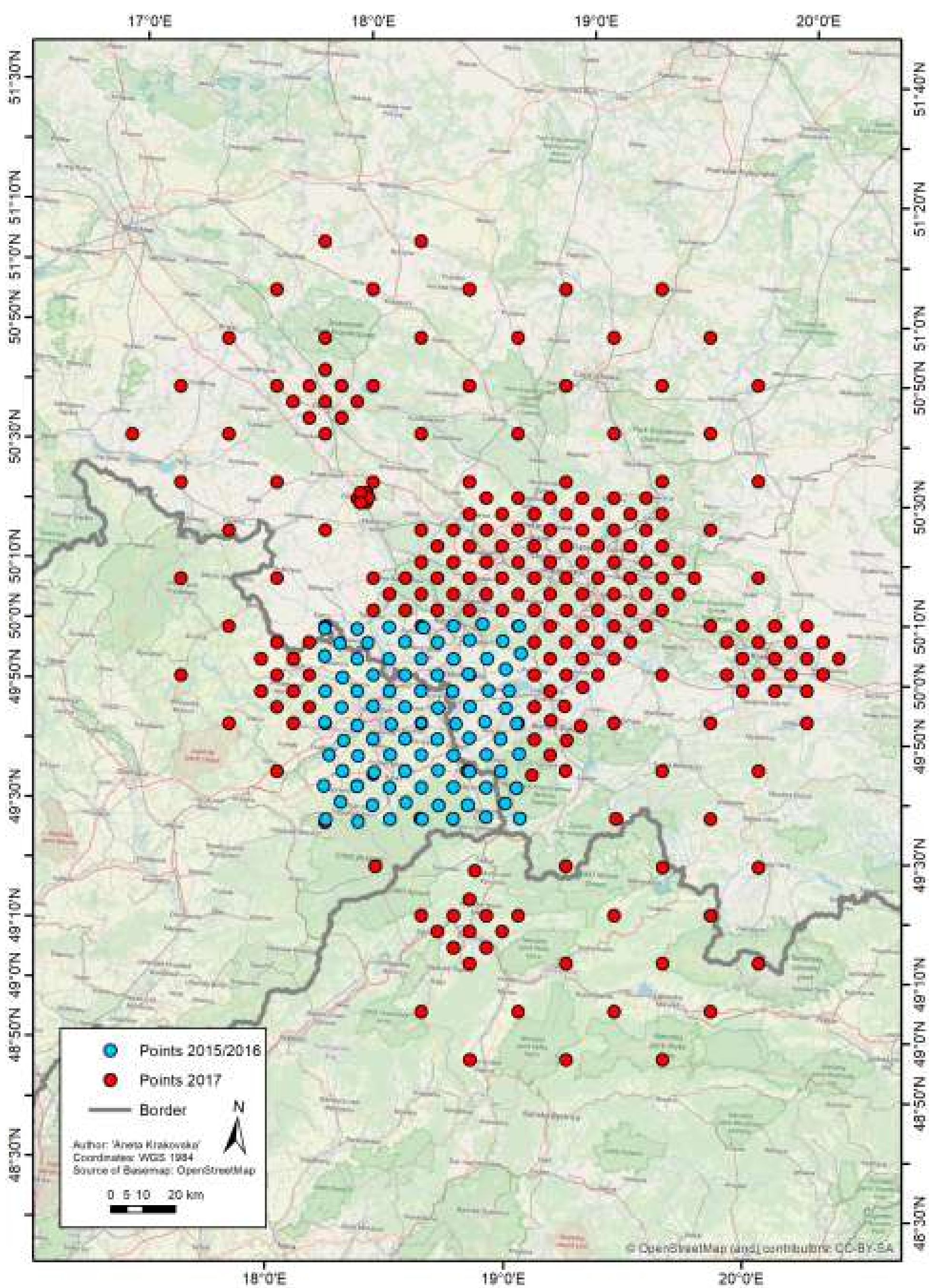
(Fernandez, Carballeira, 2000; Hakanson, 1980)

- **The contamination factors were calculated by dividing each value by the corresponding background level of that element**
- **Determines whether a specific element indicates pollution or not**

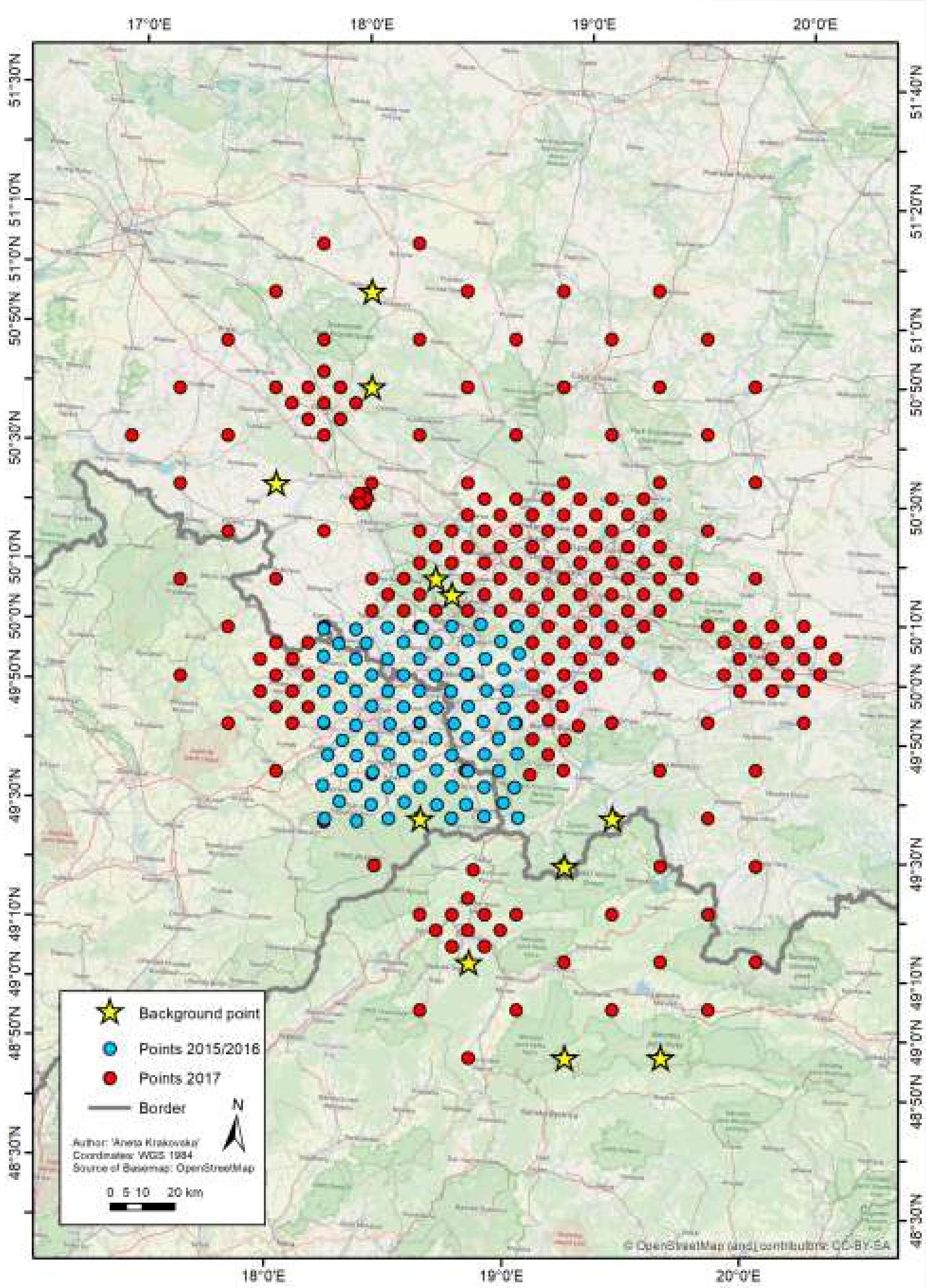
$$C_f = \frac{value}{background}$$

- < 1 no contamination;
- 1–2 suspected;
- 2–3.5 slight;
- 3.5–8 moderate;
- 8–27 severe;
- > 27 extreme.

Background


17°0'E
18°0'E
19°0'E
20°0'E
Points 2015/2016
Points 2017
Border
N
Author: 'Aneta Krakovska'
Coordinates: WGS 1984
Source of Basemap: OpenStreetMap
0 5 10 20 km
© OpenStreetMap (and) contributors, CC-BY-SA

Background



Background point
Points 2015/2016
Points 2017
Border
Author: 'Aneta Krakovska'
Coordinates: WGS 1984
Source of Basemap: OpenStreetMap
0 5 10 20 km
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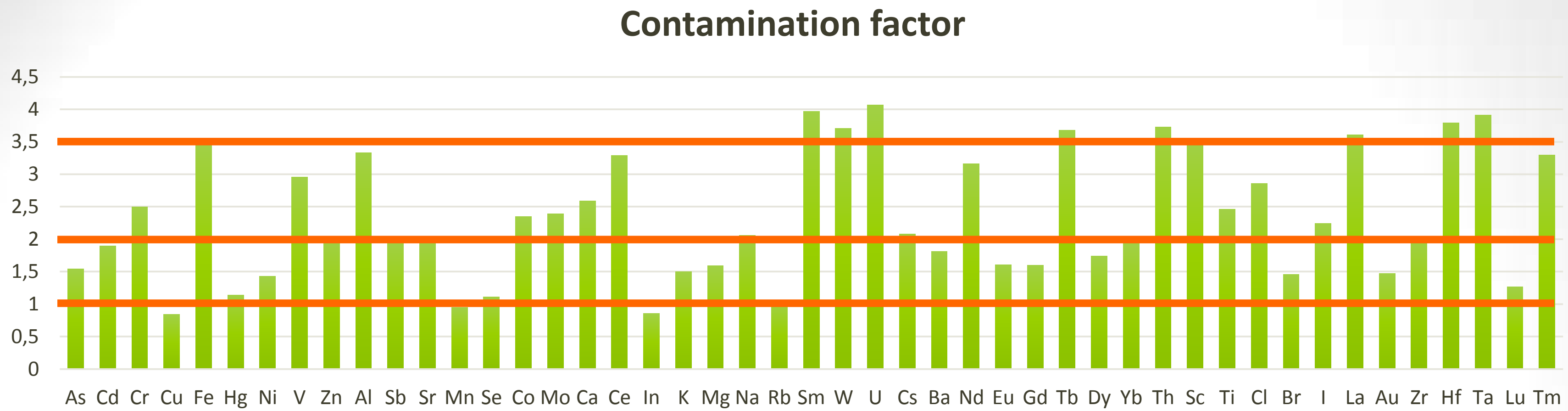
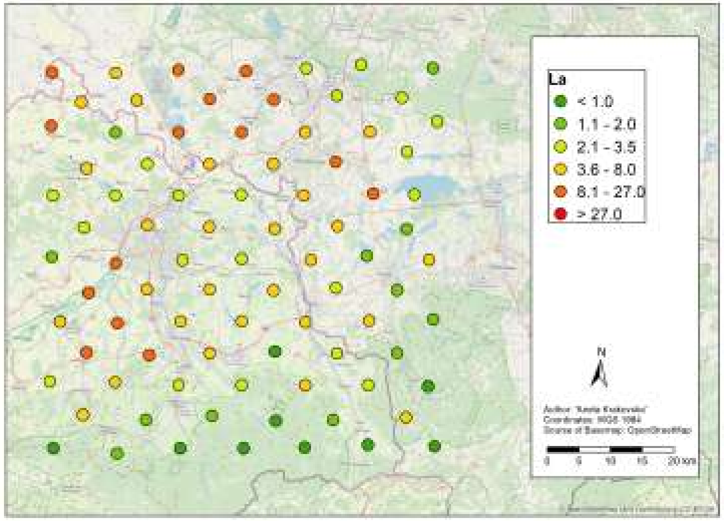
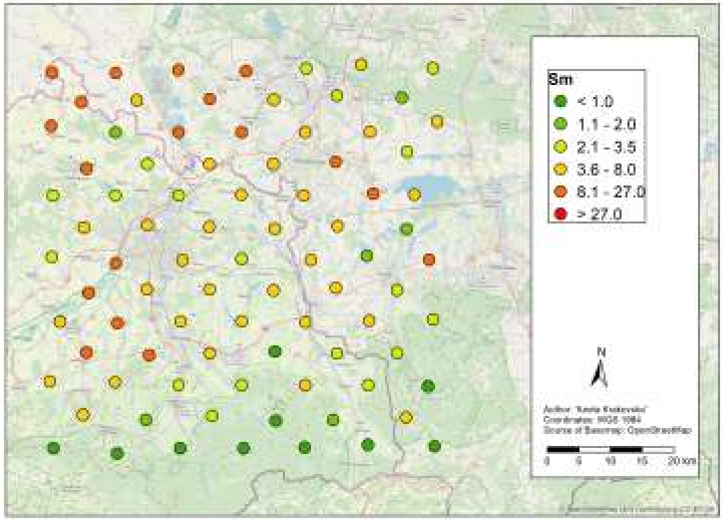


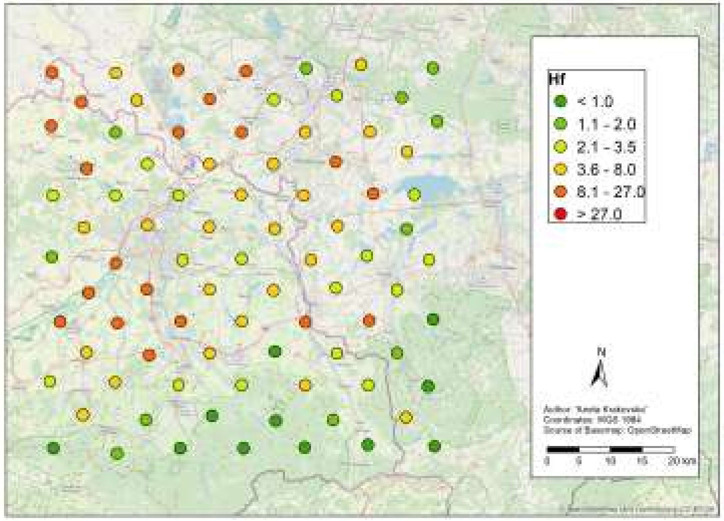
To assess contamination using contamination factors (CFs), a scale was established that allowed categorization of sampling sites for each element determined.

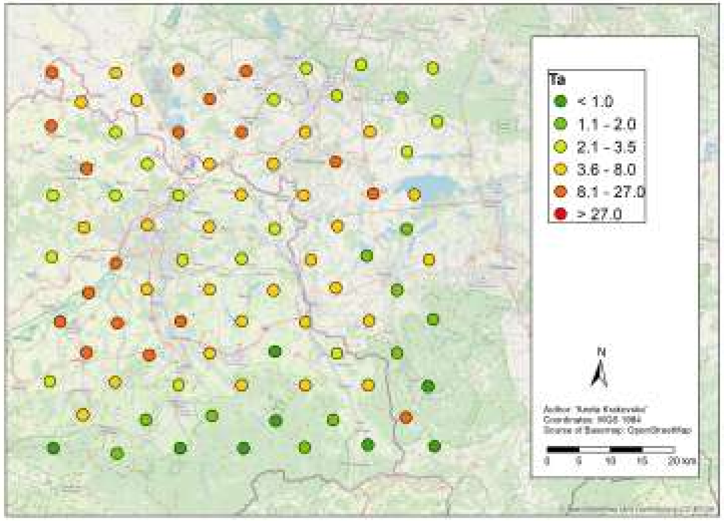
- < 1 no contamination;
- 1–2 suspected;
- 2–3.5 slight;
- 3.5–8 moderate;
- 8–27 severe;
- > 27 extreme.

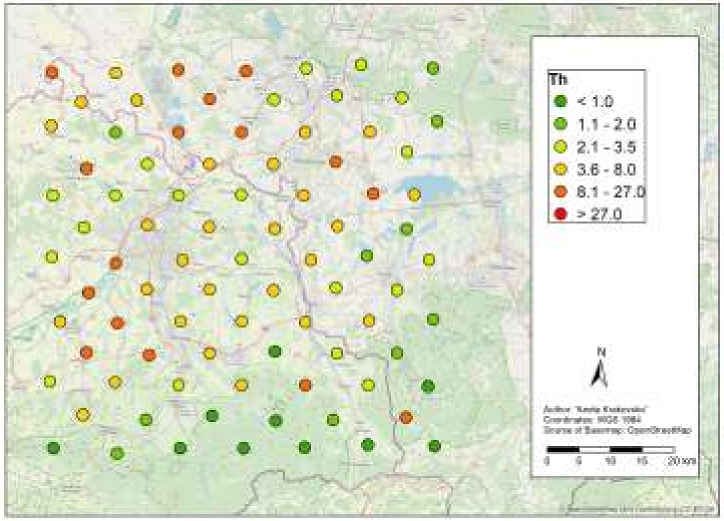
No contamination	Suspected	Slight	Moderate
Cu	Rb	Zr	La
In	Se	Na	Tb
Mn	Hg	Cs	W
	Lu	I	Th
	Ni	Co	Hf
	Br	Mo	Ta
	Au	Ti	Sm
	K	Cr	U
	As	Ca	
	Mg	Cl	
	Gd	V	
	Eu	Nd	
	Dy	Ce	
	Ba	Tm	
	Cd	Al	
	Yb	Fe	
	Sb	Sc	
	Sr		
	Zn		

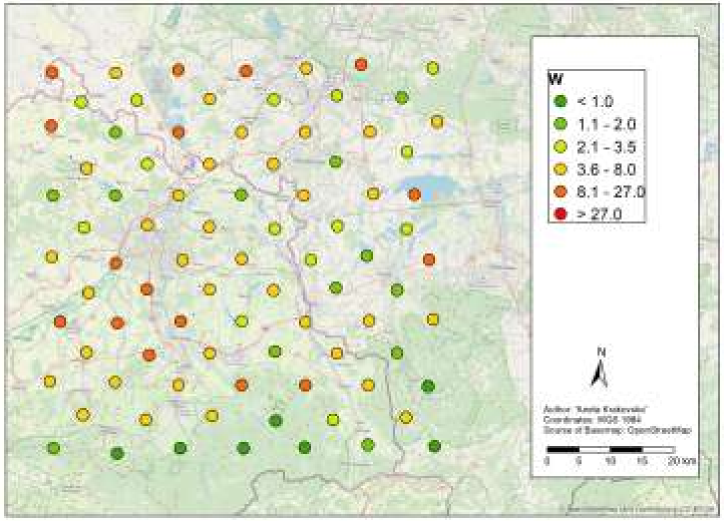

La
< 1.0
1.1 - 2.0
2.1 - 3.5
3.6 - 8.0
8.1 - 27.0
> 27.0
N
0 5 10 15 20 km

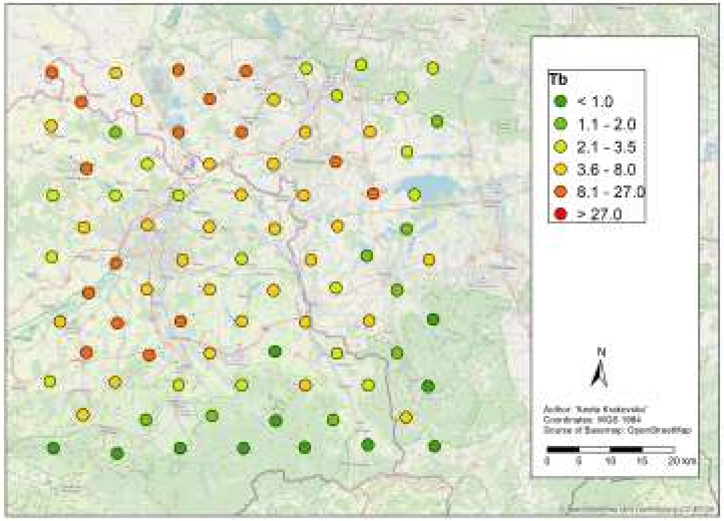

Sm
< 1.0
1.1 - 2.0
2.1 - 3.5
3.6 - 8.0
8.1 - 27.0
> 27.0
N
0 5 10 15 20 km

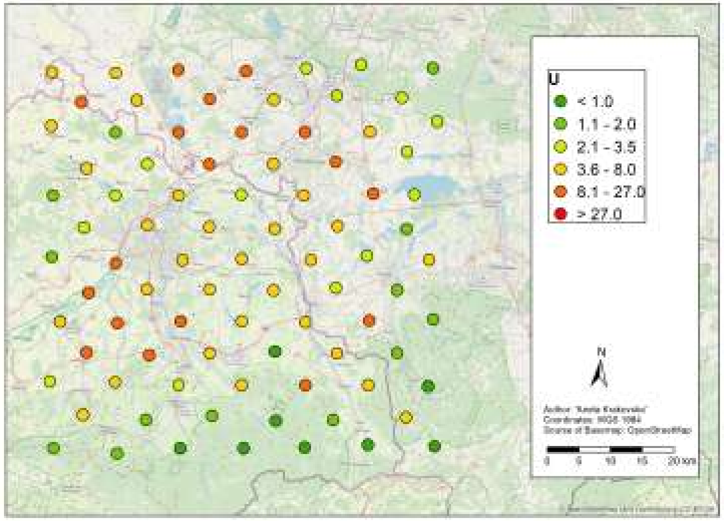

Hf
< 1.0
1.1 - 2.0
2.1 - 3.5
3.6 - 8.0
8.1 - 27.0
> 27.0
N
0 5 10 15 20 km


Ta
< 1.0
1.1 - 2.0
2.1 - 3.5
3.6 - 8.0
8.1 - 27.0
> 27.0
N
0 5 10 15 20 km


Th
< 1.0
1.1 - 2.0
2.1 - 3.5
3.6 - 8.0
8.1 - 27.0
> 27.0
N
0 5 10 15 20 km


W
< 1.0
1.1 - 2.0
2.1 - 3.5
3.6 - 8.0
8.1 - 27.0
> 27.0
N
0 5 10 15 20 km


Tb
< 1.0
1.1 - 2.0
2.1 - 3.5
3.6 - 8.0
8.1 - 27.0
> 27.0
N
0 5 10 15 20 km


U
< 1.0
1.1 - 2.0
2.1 - 3.5
3.6 - 8.0
8.1 - 27.0
> 27.0
N
0 5 10 15 20 km

Conclusion

- Factor analysis show arguable results
  - Not all elements represent factor where they are contained
  - Alteration of data pre-processing?
- Contamination factor
  - Indicated substantial difference between background and measure concentration in Rare earth elements
  - Confirm highest pollution location around mining and industry cities

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Thanks for your attention