Joint Institute for Nuclear Research

L.N. Gumilyov Eurasian National University

Mosses as bioindicators of air pollution with potentially toxic elements in area with different level of anthropogenic load in Karaganda region, Kazakhstan

Omarova Nuriya Moldagalievna

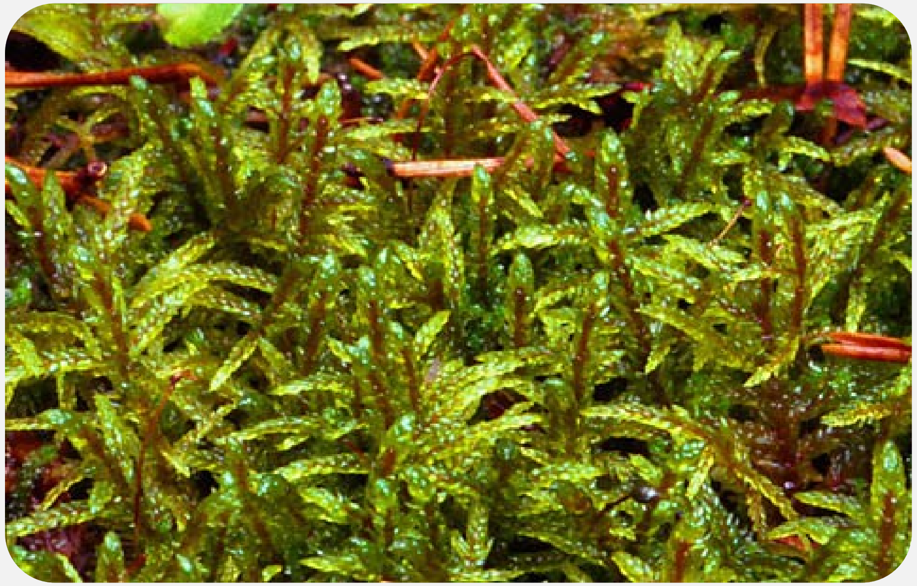
Scientific and practical significance:

In the field of biomonitoring of atmospheric fallout, a project group with L.N. Gumilev ENU cooperates with the Joint Institute for Nuclear Research (JINR) of the Russian Federation. The UN Convention on Long-Range Transboundary Air Pollution is interested in expanding the UN Program to Kazakhstan and Central Asian countries (projects should be supported by grants from the governments of these countries). In 2015, Kazakhstan entered this UN Program. (http://icpvegetation.ceh.ac.uk/).

Sampling

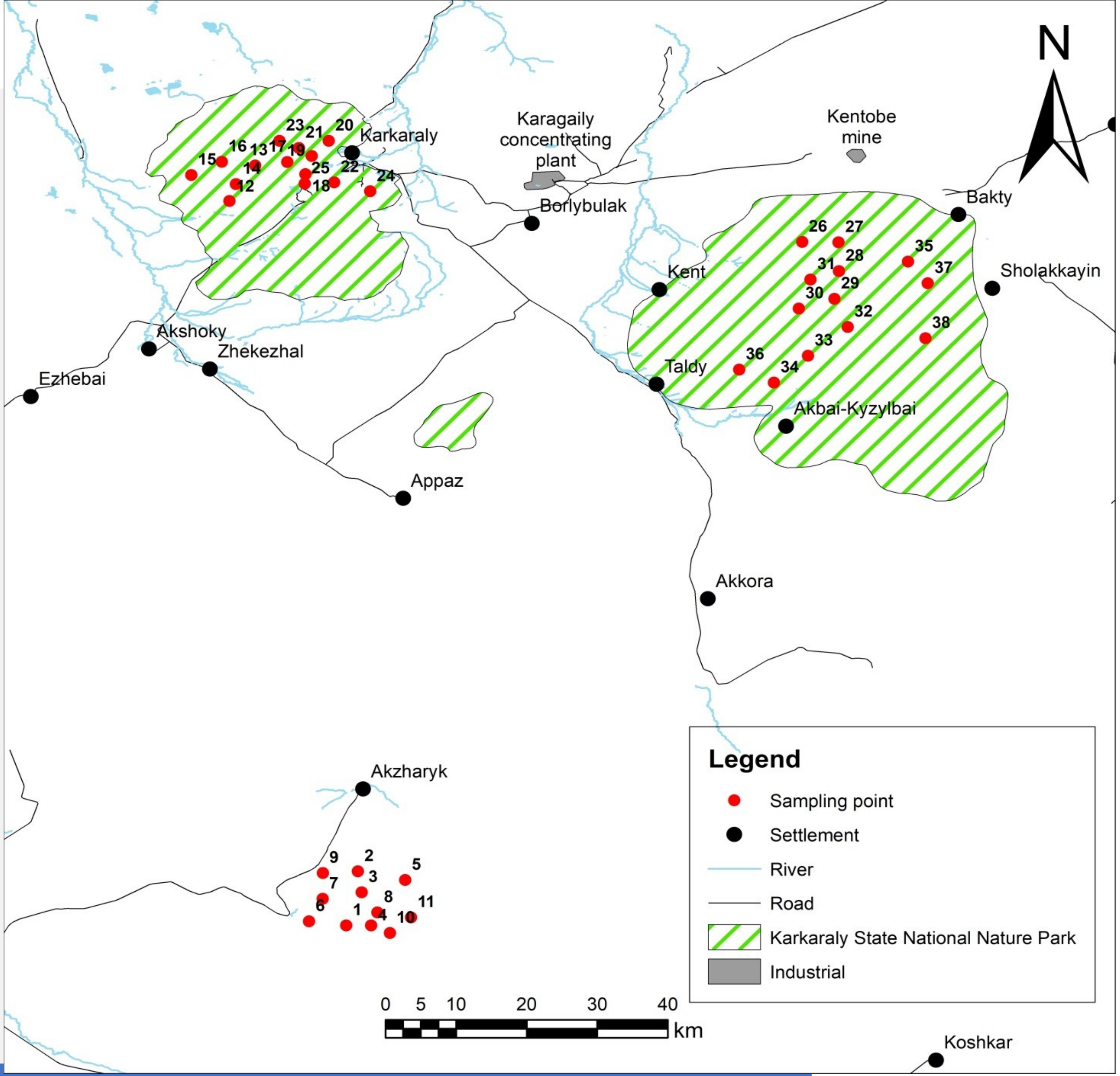
Sampling was carried out in the fall of 2018 in the Central Kazakhstan region. In the summer of 2018, another 36 samples were collected from the region. Sampling was carried out within the framework of the United Nations Air Europe Program (UNECE ICP Vegetation) using generally accepted international methodology.

Hylocomium splendens



Pleurozium schreberi

Fig. 1 Sampling map for Karaganda region



For the first time, moss biomonitoring was carried in Karaganda region, Kazakhstan. The studied area covered two territories with different level of anthropogenic load: the Karkaraly National Park and the Akzharyk settlement. The level of 36 major, minor and trace elements was determined in mosses collected at studies areas using neutron activation analysis and three elements, Cu, Cd and Pd were detected applying atomic absorption spectrometry. To reveal any associations of elements and to match them with possible emission sources factor analysis was applied. The contamination factor, pollution load index, and environmental risk were computed in order to evaluate the degree of pollution in the examined area and the effects of various elements on human health.

Table 1 The descriptive statistics for moss samples (in mg kg^{-1}) collected in Akzharyk village and Karkaraly National Park in the Karaganda region

Element	*Akzharyk village*				*Karkaraly + National Park*			
	Range	Median	Mean ± st.dev	CV (%)	Range	Mean ± st.dev	Median	CV (%)
Na	318–2060	768	905 ± 607	67	187–1870	482 ± 336	427	69
Mg	1850–5850	3650	3478 ± 1241	35	1180–3860	1940 ± 650	1690	33
Al	967–11,600	3490	5002 ± 3467	69	1200–6500	2504 ± 1142	2180	45
Cl	56–2290	1110	1023 ± 935	91	57–1400	162 ± 250	113	153
K	4070–15800	10,800	9683 ± 4151	42	3330–18200	5911 ± 2762	5580	46
Ca	5300–15700	10,100	11,035 ± 3646	33	3970–12300	6778 ± 2173	6270	32
Sc	0.3–5	0.84	1.2 ± 1.3	109	0.1–1.18	0.5 ± 0.2	0.45	47
Ti	59–525	174	217 ± 147	67	39–359	118 ± 71	111	60
V	1.37–18	5.5	6.2 ± 4.6	75	0.8–8.5	3.3 ± 1.6	2.96	47
Cr	3.2–15.2	7.4	7.81 ± 4.14	52	3.2–9.2	5.7 ± 1.64	5.2	28
Mn	103–329	135	167 ± 75	45	53–584	195 ± 130	159	66
Fe	821–5050	1920	2392 ± 1403	58	501–3250	1463 ± 618	1350	42
Co	0.45–1.47	0.8	0.82 ± 0.34	42	0.33–1.26	0.67 ± 0.24	0.61	35
Ni	1.43–6.2	4.7	3.98 ± 1.69	42	1.1–3.95	2.47 ± 0.81	2.33	32
Zn	36–150	77	88.68 ± 39.2	44.2	16.5–179	49.91 ± 31.17	46	62
As	0.87–3.16	1.38	1.6 ± 0.76	47.39	0.21–2.1	1.09 ± 0.42	1.05	38
Se	0.16–0.84	0.32	0.41 ± 0.2	49.62	0.04–1.13	0.56 ± 0.28	0.48	50
Br	2.5–48	16	18.3 ± 15.37	84	1.5–20.5	5.78 ± 3.52	4.9	60
Rb	8.6–35	15.3	17.53 ± 8.68	49	4.95–38	10.85 ± 7.04	9.2	64
Sr	20.4–89	69	58.23 ± 22.95	39	18–93	31.36 ± 14.04	30	44
Zr	2.97–55	13	22.83 ± 19.05	83	2.3–16	6.72 ± 3.21	7.1	47
Sb	0.09–0.54	0.15	0.2 ± 0.14	67	0.04–0.78	0.22 ± 0.13	0.2	61
I	0.77–30	2.02	5.2 ± 8.44	162	0.63–4.6	1.74 ± 0.88	1.46	50
Cs	0.28–12.2	0.61	2.33 ± 3.67	157	0.08–8.2	0.59 ± 1.53	0.26	258
Ba	10.7–135	44	53.1 ± 32.9	61	40–305	152 ± 64.7	164	42
La	0.98–55	4.3	13.28 ± 16.55	124	0.74–7.6	2.37 ± 1.6	1.54	67
Ce	1.62–27.6	4.55	10.07 ± 9.29	92	0.96–15	4.09 ± 3.06	3.14	74
Nd	0.15–49	6.1	13.66 ± 16.18	118	0.15–9.7	2.76 ± 2.43	2.43	88
Sm	0.22–12	1.45	3.47 ± 3.99	115	0.12–2.6	0.56 ± 0.53	0.32	94
Eu	0.03–0.86	0.17	0.3 ± 0.3	105	0.01–0.11	0.05 ± 0.03	0.05	54
Tb	0.04–3.46	0.37	0.99 ± 1.16	117	0.02–0.5	0.1 ± 0.1	0.06	104
Dy	0.2–24.6	1.98	7.9 ± 9.5	119	0.1–3.54	0.8 ± 0.9	0.3	117
Tm	0.04–4.5	0.54	1.37 ± 1.57	114	0.0046–0.34	0.07 ± 0.07	0.05	101
Hf	0.07–0.88	0.19	0.29 ± 0.24	83	0.07–0.42	0.15 ± 0.08	0.12	52
Ta	0.02–0.29	0.06	0.09 ± 0.08	90	0.01–0.11	0.04 ± 0.03	0.03	70
W	0.16–3	0.34	0.85 ± 0.93	108	0.08–0.94	0.34 ± 0.18	0.28	53
Au	0.001–0.007	0.0019	0.003–0.002	74	0.001–0.026	0.006 ± 0.007	0.0026	111
Th	0.25–12	0.7	1.9 ± 3.4	174	0.19–1.4	0.4 ± 0.2	0.38	57
U	0.11–67	7.7	14.9 ± 22.5	151	0.06–2.47	0.2 ± 0.4	0.12	208
Cu*	5.43–21.88	9.55	11.0 ± 4.7	43	6.89–17.2	10.5 ± 3.0	9	29
Cd*	0.15–0.52	0.21	0.2 ± 0.1	43	0.03–0.49	0.2 ± 0.1	0.21	41
Pb*	2.76–16.71	7.43	7.8 ± 3.5	45	1.47–9.34	6.4 ± 2.1	6.62	33

*-elements determined by AAS, CV- coefficient of variation

Fig. 2 Content of Cr, Ni, Cu and Fe in mosses collected in Karaganda region (in mg/kg)

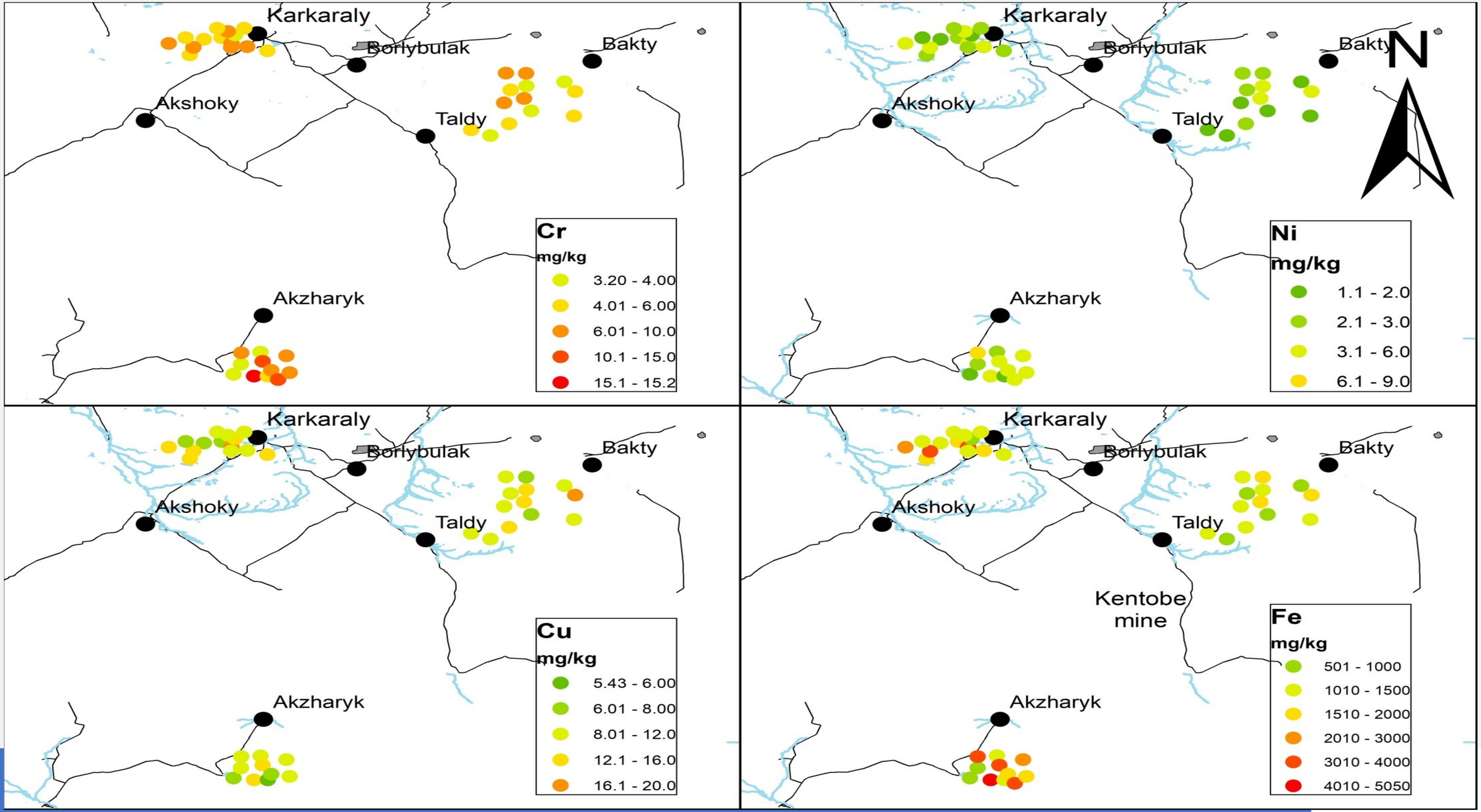
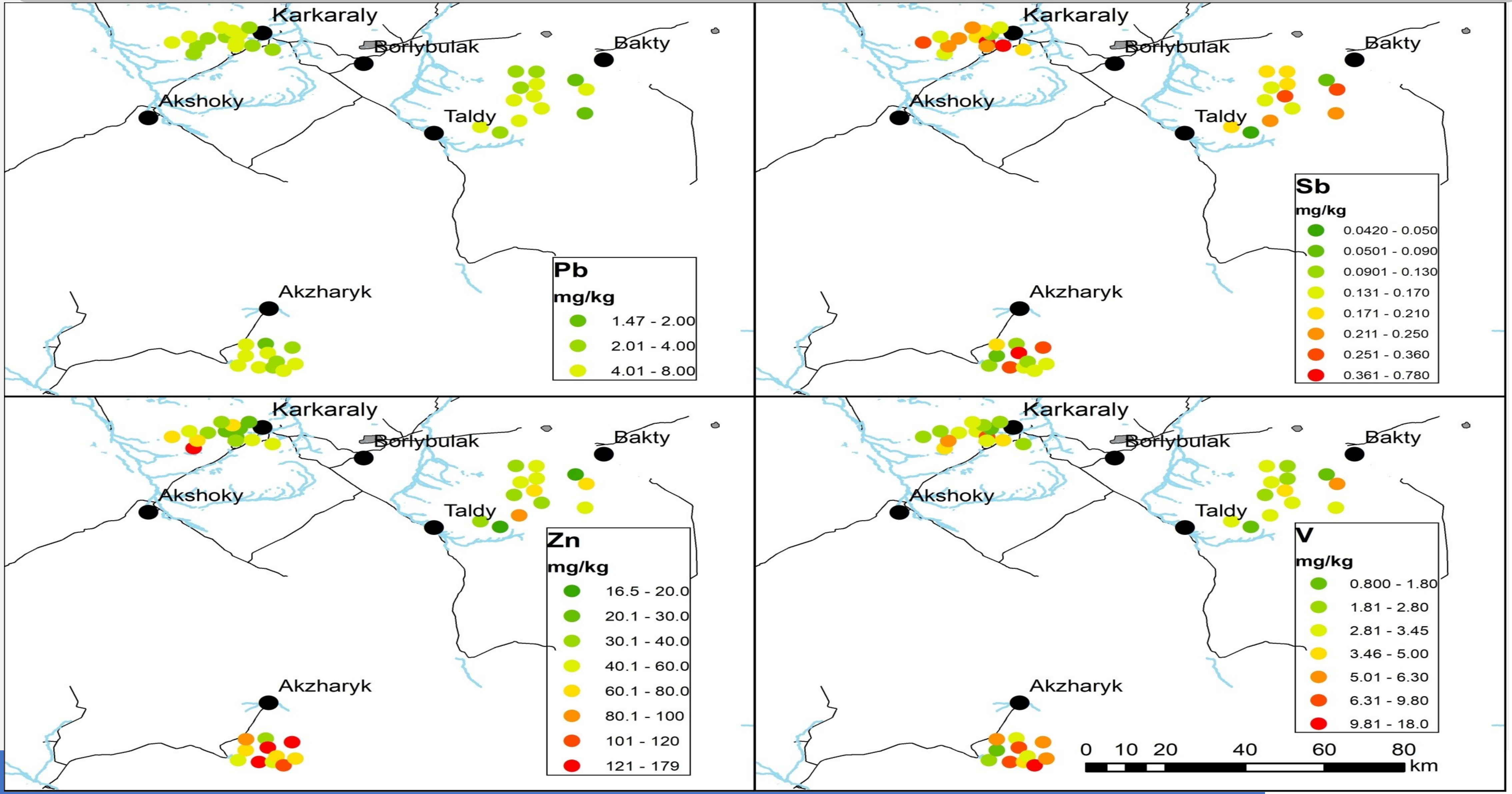


Fig. 3 Content of Pb, Sb, Zn and V in mosses collected in Karaganda region (in mg/kg)



Mann–Whitney U Test

The comparison of the elements concentrations between mosses collected in Akzharyk village and Karkaraly National Park by the Mann–Whitney U Test ($p < 0.05$) showed that mosses collected in Akzharyk village contained significantly higher concentrations of Na, Mg, Al, Cl, K, Ca, Se, V, Ni, Zn, Br, Rb, Sr, Zn, Cs, Ba, La, Ce, Th, Sm, Eu, Tb, Dy, Tm, Hf, Ta, Th. The mentioned elements can be attributed to natural sources as well as resuspended road dust. There was no difference in concentration of elements, which can be associated with mining, industrial activity and vehicles: Ti, Cr, Mn, Fe, Co, As, Se, Sb, I, Nd, W, Au, U, Cu, Cd and Pb. Thus, it can be concluded that elements emitted as the result of industrial or mining activ- ity can be adsorb to the surface of particles and migrate with meteorological activity, thus contaminating other areas. According to Vinogradova et al. heavy metals can be deposited at a large distance from the emission sources.

Table 2 Comparison of the Karaganda region's mean values for selected elements with the data reported for neighboring countries, in mg/kg

Element	Karaganda region	Russia	Mongolia	Tajikistan	Azerbaijan	Georgia
As	1.1	0.49	2.3	6.42	1.16	0.98
Cd	0.21	0.28	0.59	0.36	0.11	0.14
Cr	5.4	4.13	8.7	23.2	9.24	7.74
Cu	9.27	6.03	nd	13.2	9.26	5.15
Fe	1395	925	4310	8280	3045	2720
Ni	2.45	2.55	3.88	11.4	6.08	5.52
Pb	6.95	0.81	nd	6.90	nd	5.29
V	3.1	2.65	10	27	8.29	9.47
Zn	49	43.1	47.1	50.9	32.3	27.7
Al	2435	1450	8070	15,700	4225	4240
Sb	0.198	0.14	0.32	1.5	0.14	0.16

Table 2 Comparison of the Karaganda region's mean values for selected elements with the data reported for neighboring countries, in mg/kg

Four factors, accounting for 80% of the treated elements' variability, were found through the application of factor anal- ysis. Table 3 displays the matrix of rotated factor loadings. The main sources of air pollution in the studied areas can be considered soil erosion, mining, ore processing, industrial activities, transport and thermal power plants. The influence is provided by nearby indus-trial zones such as the Karagaily mining and processing plant and the Kentobe deposit.

Table 3 Matrix of rotated factor loadings (Box-Cox transformation applied

Element	Factor 1	Factor 2	Factor 3	Factor 4
Cd	0.41	-0.20	0.30	0.48
Cu	0.66	0.18	0.21	0.45
Mn	-0.05	0.13	0.04	0.77
Fe	0.53	0.69	0.35	0.26
Ni	0.28	0.50	0.65	0.28
Co	0.49	0.57	0.26	0.32
Zn	0.28	0.25	0.65	0.33
As	0.23	0.48	0.45	0.59
Br	0.54	−0.01	0.81	−0.05
V	0.86	0.29	0.31	0.17
Ti	0.81	0.44	0.14	0.21
Sc	0.30	0.90	0.17	0.13
Al	0.71	0.59	0.27	0.08
U	0.04	0.33	0.79	−0.08
W	0.81	0.42	0.29	0.02
Sb	0.31	0.19	0.04	0.61
Th	0.16	0.91	0.08	0.08
Ca	0.20	0.06	0.77	0.25
Cr	0.50	0.67	0.34	0.23
Expl.Var	4.69	4.47	3.69	2.32
Prp.Totl	0.25	0.24	0.19	0.12

Publication

Mosses as bioindicators of air pollution with potentially toxic elements in area with different level of anthropogenic load in Karaganda region, Kazakhstan

Makhabbat Nurkassimova[1] Nuriya Omarova[1] Inga Zinicovscaia[2,3]· Omari Chaligava[2,4]
Nikita Yushin[2]

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Thank you for attention!