

SUPPLEMENTARY INFORMATION

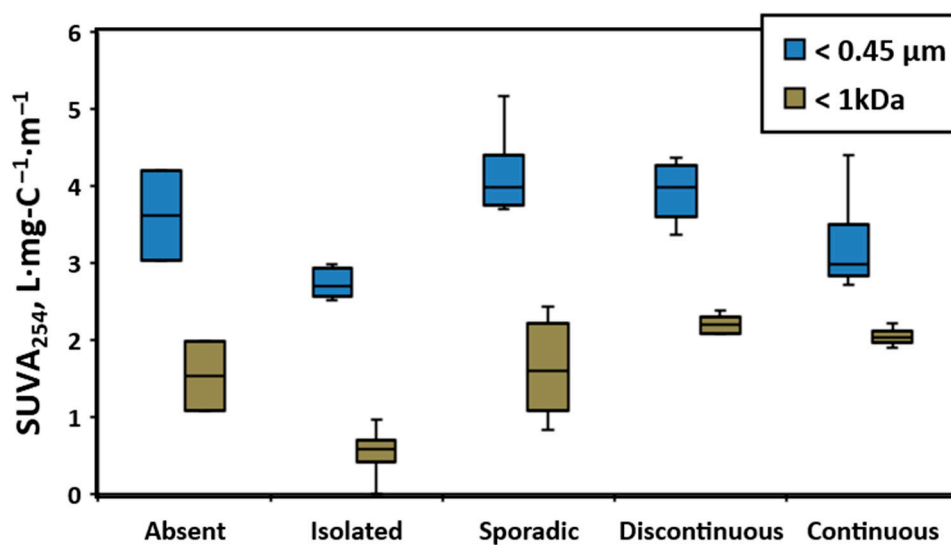


Figure S1. Box plot (median and IQR range) of SUVA₂₅₄ of the lake water in total dissolved (< 0.45 μm) and low molecular weight (LMW_{<1kDa}) dialysates across the permafrost gradient of the WSL.

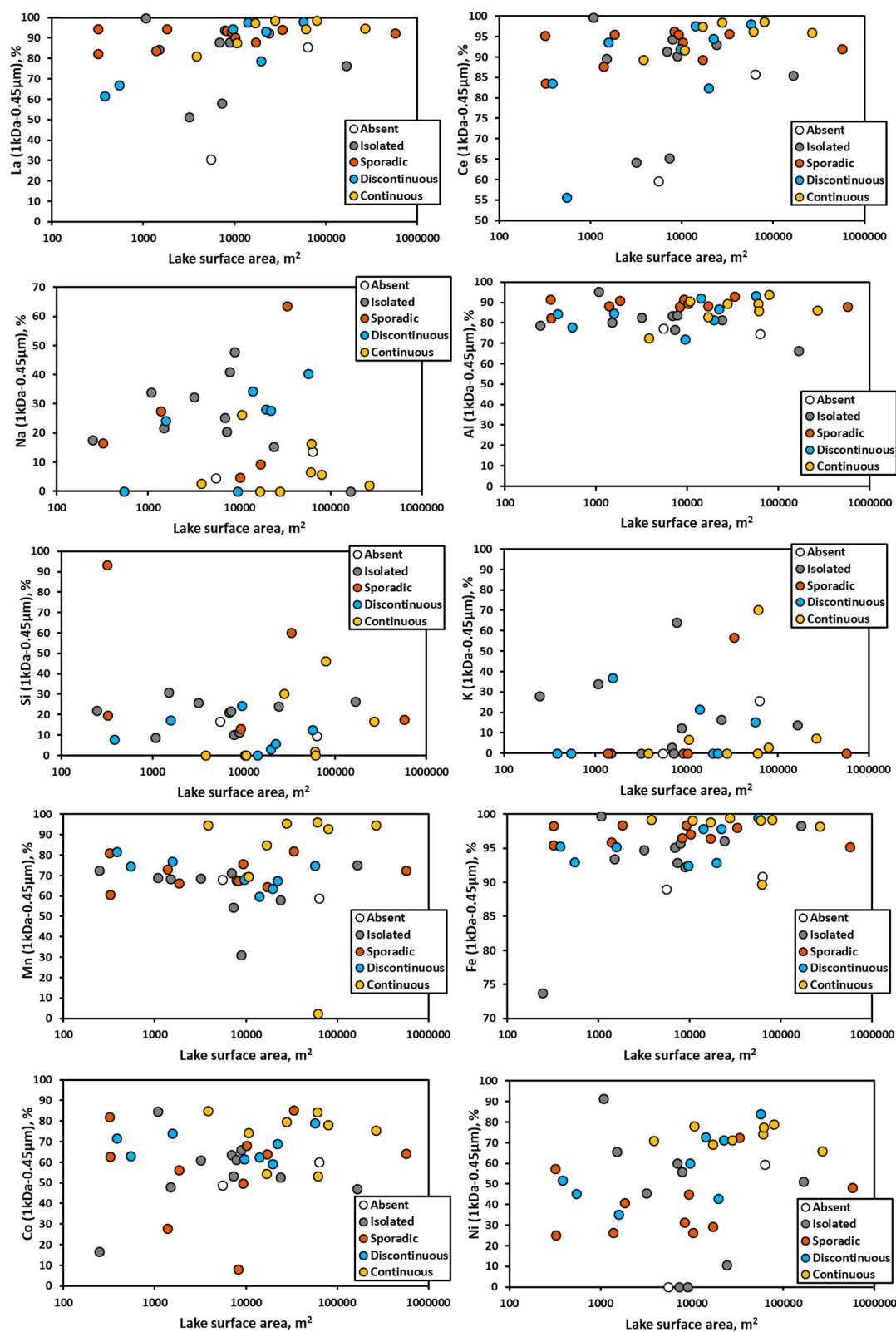


Figure S2, continued.

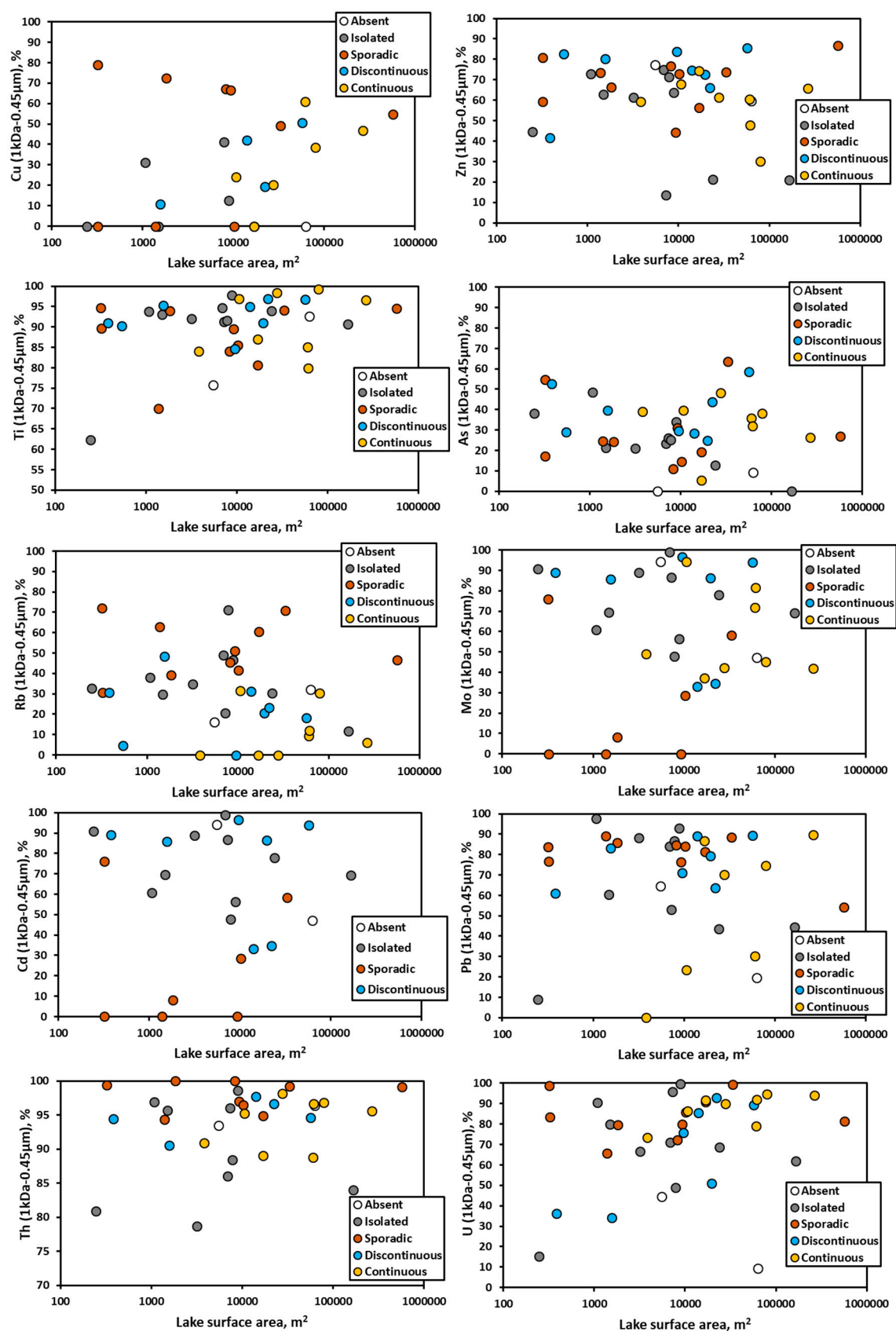


Figure S2. Dependence of element concentration in lake waters in all permafrost zones on the water surface area.

Table S1. The Spearman correlation coefficients (at, $p < 0.05$) of the percentage colloidal forms of elements depending the lake surface area in different permafrost zones of WSL.

| elements | Isolated | Sporadic | Discontinuous | Continuous | All zones |
|-----------------------------|----------|----------|---------------|------------|-----------|
| S.C., $\mu\text{S cm}^{-1}$ | -0.67 | – | -0.92 | – | -0.35 |
| pH | – | 0.63 | 0.98 | – | 0.44 |
| DOC | – | 0.77 | – | – | 0.40 |
| Li | -0.66 | – | – | – | -0.42 |
| B | – | – | – | – | -0.47 |
| Na | – | – | 0.79 | – | – |
| Mg | -0.65 | – | -0.71 | – | -0.34 |
| Ca | – | – | – | – | -0.62 |
| Cr | – | – | 0.74 | – | – |
| Ni | – | – | – | – | 0.36 |
| Sr | – | – | -0.79 | – | -0.41 |
| Cd | -0.71 | – | – | – | – |
| La | – | – | – | – | 0.37 |
| Ce | – | – | – | – | 0.35 |
| Dy | – | – | 0.86 | – | 0.48 |
| Hf | – | – | 1.00 | – | 0.48 |
| U | – | – | 0.82 | 0.81 | – |

Table S2. Correlation matrix (Spearman Rank Order Correlations) of S_{lake} (m²), pH, and DOC, Al, Fe concentrations (< 0.45 μm) and percentage of colloidal fraction (0.45 μm – 1 kDa) of major and trace elements in lake waters of different permafrost zones of WSL (at, p < 0.05).

[illegible]

| Element | Isolated | | | | | Sporadic | | | | | Discontinuous | | | | | Continuous | | | | | All zones | | | | |
|---------|----------|------|------|-----|----|----------|----|------|------|----|---------------|------|------|-----|----|------------|----|------|-------|-------|-----------|-------|------|------|------|
| | Slake | pH | Al | DOC | Fe | Slake | pH | Al | DOC | Fe | Slake | pH | Al | DOC | Fe | Slake | pH | Al | DOC | Fe | Slake | pH | Al | DOC | Fe |
| Ba | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0.79 | – | – | – | -0.62 | 0.42 | – | 0.52 |
| La | – | – | – | – | – | – | – | – | – | – | – | 0.82 | 0.79 | – | – | – | – | – | – | – | 0.37 | – | – | – | – |
| Ce | – | – | – | – | – | – | – | – | – | – | – | 0.76 | 0.76 | – | – | – | – | – | – | – | 0.35 | – | – | – | – |
| Nd | – | – | – | – | – | – | – | 0.87 | 0.76 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Gd | – | 0.89 | – | – | – | – | – | 0.67 | 0.80 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0.66 | – |
| Dy | – | – | – | – | – | – | – | – | – | – | 0.86 | 0.93 | 0.93 | – | – | – | – | – | – | – | 0.48 | 0.37 | – | – | – |
| Hf | – | – | – | – | – | – | – | – | – | – | – | – | 0.90 | – | – | – | – | – | – | – | 0.48 | – | – | 0.46 | – |
| Pb | – | 0.65 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | -0.89 | -0.82 | – | – | – | – | – |
| Th | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0.58 | – | – |
| U | – | – | 0.66 | – | – | – | – | – | – | – | 0.82 | 0.89 | 0.93 | – | – | 0.81 | – | – | – | -0.81 | – | – | – | – | – |

Table S3. The groups of elements depending colloidal status in lakes from different permafrost zone of WSL.

| Permafrost zones | Percentage colloidal fraction, % | Elements |
|----------------------|----------------------------------|--|
| Absent | < 40 | Cs, Ni, U, Rb, SO ₄ , Si, K, B, Na, As, V, DIC |
| | 40–80 | Co, Tl, Hf, Ge, Be, Cr, Pb, Li, Al, Mo, Sr, Mn, Ba, Mg, DOC, Cd, Ca, Ga, Zn, REEs |
| | > 80 | Nb, Th, Zr, Fe, Ti, Y |
| Isolated | < 40 | Ge, Rb, Li, B, Na, As, Si, K, Cu, DIC, V, Sb |
| | 40–80 | Ba, Co, Cd, Zn, Tl, Ni, Cs, Ga, Mo, Cr, Hf, U, DOC, Pb, Be, Sr, Mg, Mn, Ca, HREEs |
| | > 80 | Fe, Zr, Ti, Th, Al, Y, LREEs |
| Sporadic | < 40 | Cr, Li, Si, Cd, As, Mo, Na, Sb, Mg, B, Ge, K, V, DIC, Be |
| | 40–80 | Co, Cs, Rb, Ni, Cu, Sr, Ba, Mn, Ga, Zn, Hf, DOC, Tl, HREEs |
| | > 80 | Fe, Th, Al, Zr, Ti, Nb, Ca, U, Pb, LREEs |
| Discontinuous | < 40 | As, Ge, Li, Cu, V, Na, Rb, DIC, K, Si, Sb |
| | 40–80 | Ni, Cr, P, Cd, SO ₄ , Cs, Pb, B, Mo, Zn, Sr, Ba, Mn, Mg, Ca, Co, Tl, U, DOC, Be |
| | > 80 | Fe, Ti, Al, Ga, Zr, Hf, Nb, Y, REEs |
| Continuous | < 40 | Ba, Cs, As, Cu, Ca, Sr, Mg, Li, Si, K, Rb, Na, Sb, B, DIC |
| | 40–80 | Zn, Mo, Ge, Pb, V, Tl, Mn, Ni, Co, Cr, DOC, Gd |
| | > 80 | Zr, Fe, Nb, Ti, U, Al, Hf, Be, Ga, Y, REEs |
| All permafrost zones | < 40 | Ge, Li, Cu, Rb, B, As, V, Si, Na, K, DIC, Sb |
| | 40–80 | Cr, Tl, Be, Ni, Cd, Mg, Cs, Ga, Hf, Mn, U, DOC, Zn, Pb, Ca, Sr, Co, Ba, Mo, HREEs |
| | > 80 | Fe, Th, Nb, Zr, Ti, Al, Y, LREEs |

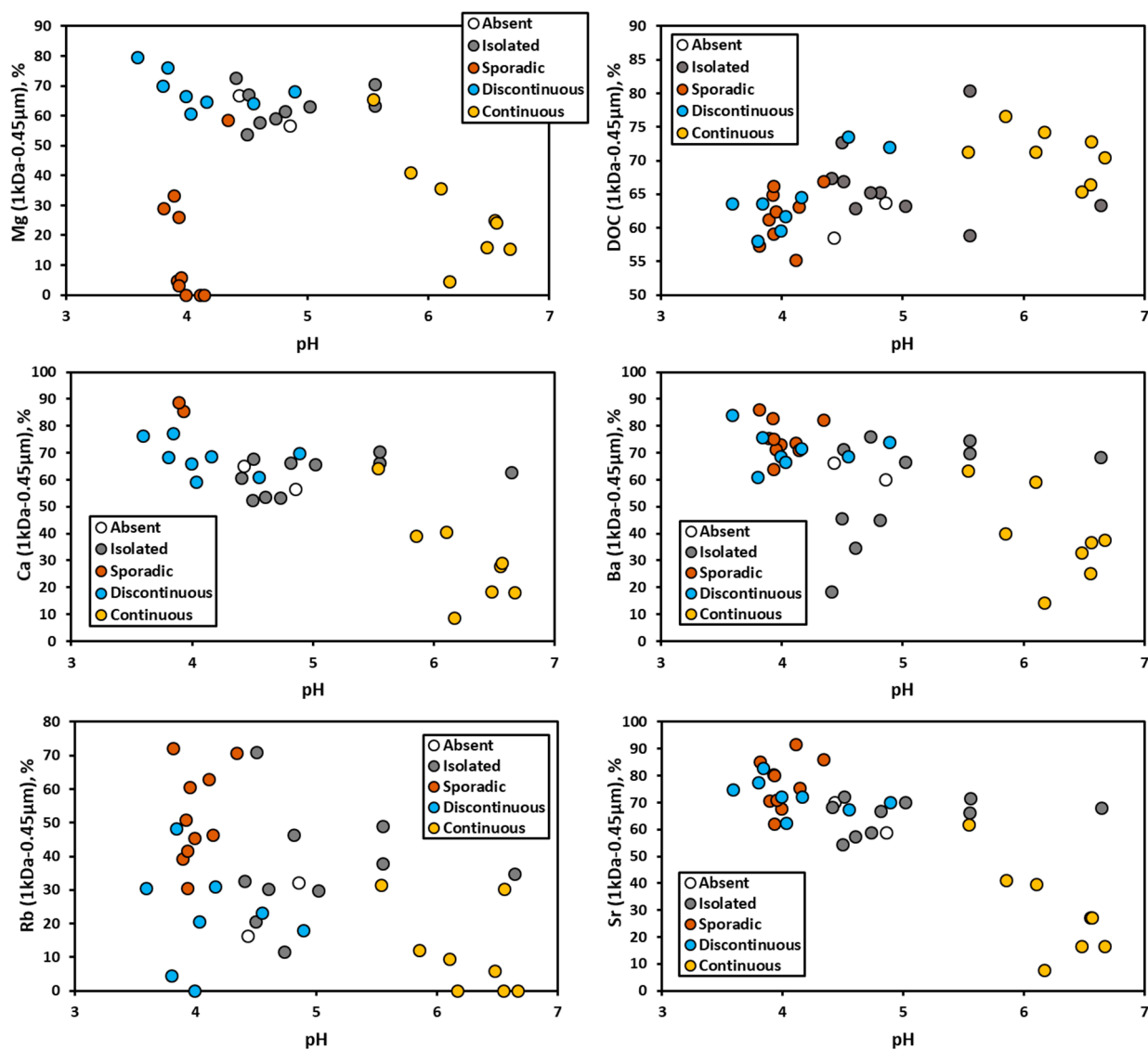


Figure S3. Some depending of the chemical elements colloidal status from pH level of lake waters.

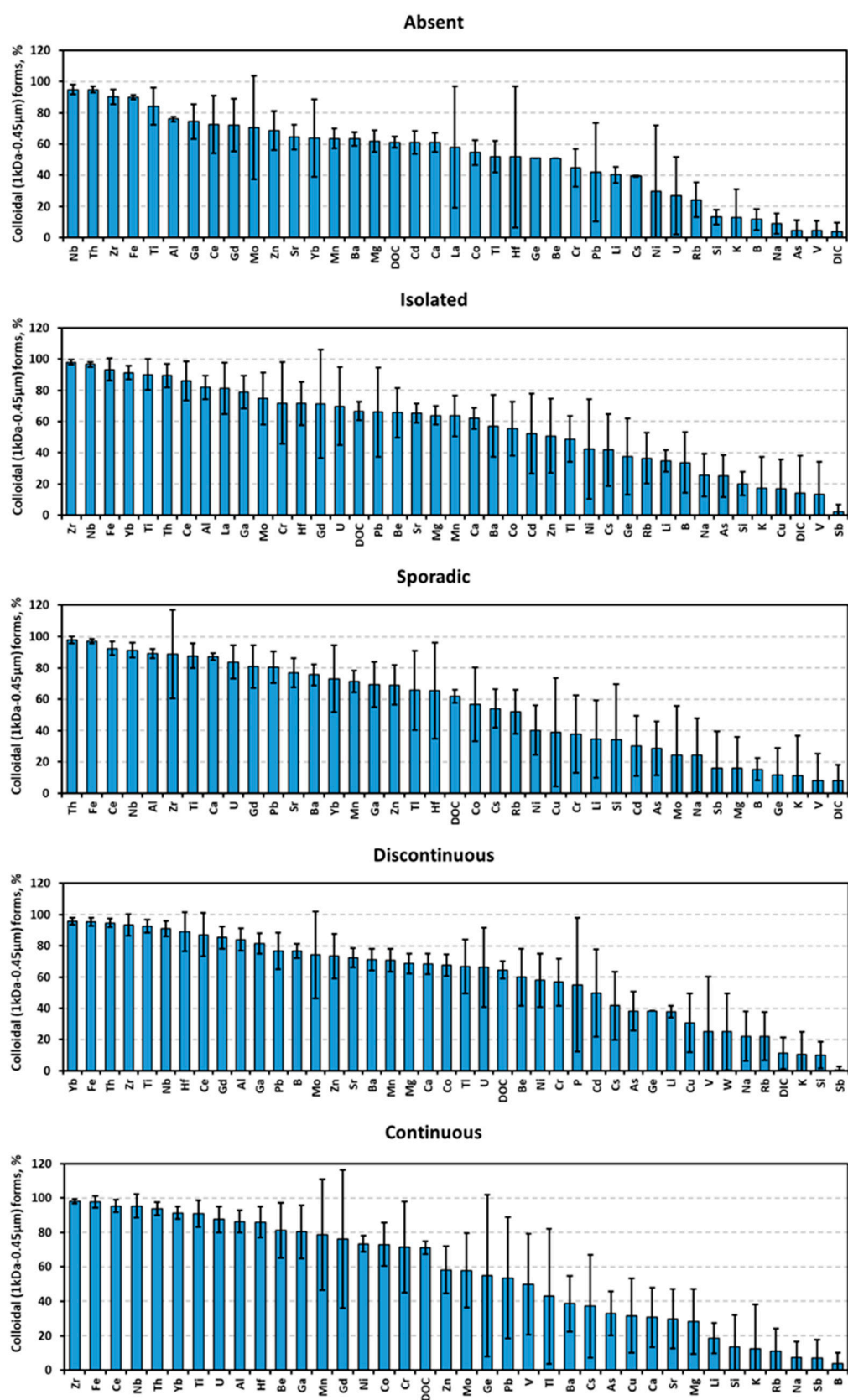


Figure S4. Percentage of the colloidal fraction of chemical elements in lake waters of different permafrost zones of Western Siberia.

Table S4. Mann-Whitney U test of the difference in percentage between colloidal fractions in lake water of different permafrost zones. Only statistically significant values are presented (at, $p < 0.05$).

[illegible]

| | Isolated vs Sporadic | | | Isolated vs Discontinuous | | | Isolated vs Continuous | | | Sporadic vs Discontinuous | | | Sporadic vs Continuous | | | Discontinuous vs Continuous | | |
|----|----------------------|-------|---------|---------------------------|-------|---------|------------------------|-------|---------|---------------------------|-------|---------|------------------------|-------|---------|-----------------------------|-------|---------|
| | U | Z | P-value | U | Z | p-value | U | Z | p-value | U | Z | p-value | U | Z | P-value | U | Z | p-value |
| Ba | 17 | -2.46 | 0.01 | – | – | – | 16 | 2.09 | 0.04 | – | – | – | 0 | 3.51 | <0.01 | 1 | 3.20 | <0.01 |
| Tb | – | – | – | – | – | – | 3 | -2.27 | 0.02 | – | – | – | 5 | -2.12 | 0.03 | 6 | -1.98 | 0.05 |
| Dy | – | – | – | – | – | – | – | – | – | – | – | – | 7 | -2.74 | 0.01 | – | – | – |
| Ho | – | – | – | 10 | -2.03 | 0.04 | – | – | – | 12 | -2.01 | 0.04 | 15 | -1.97 | 0.05 | – | – | – |
| Tl | – | – | – | 10 | -2.03 | 0.04 | – | – | – | – | – | – | – | – | – | – | – | – |
| Th | 11 | -2.56 | 0.01 | – | – | – | – | – | – | – | – | – | 14 | 2.07 | 0.04 | – | – | – |

Table S5. Percentage of measured colloidal (1–3 kDa – 0.45 µm) forms in peat porewaters [25], rivers [24], and lakes (this study) in the permafrost affected zone of WSL (mean ± SD).

| Parameter | Peat porewaters | Lakes | Rivers |
|-----------|-----------------|-----------|-----------|
| DOC | 51.2±11.9 | 65.1±4.6 | 40.6±12.8 |
| Li | 7.7±16.8 | 33.2±10 | 3.8±9.04 |
| B | 19±5.4 | 28.2±8.8 | 7.81±15 |
| Na | 44.7±13.9 | 17.7±13.8 | 11.6±19.1 |
| Mg | 40.1±17.3 | 47.8±11.7 | 11.7±13.7 |
| Al | 56.6±12.3 | 83.4±5.2 | 62.9±25.8 |
| Si | 7.6±5.3 | 18.2±15 | 4.14±9.92 |
| P | 49.7±19.6 | – | 45.7±25.1 |
| K | 63.3±7.4 | 12.9±20.8 | 12.3±18.7 |
| Ca | 48.7±15.7 | 61.8±7.7 | 17.4±21.4 |
| Ti | 87.4±6.8 | 89.1±8.3 | 22.3±28 |
| V | 45.2±4.7 | 20.1±21.8 | 21.4±16.3 |
| Cr | 61.1±6.4 | 56.5±20.9 | 53.4±24.9 |
| Mn | 50±5.1 | 69.6±13.2 | 41.5±26.7 |
| Fe | 62.1±8 | 94.7±3.1 | 84.7±20.3 |
| Co | 46.9±11.3 | 61.5±13.7 | 54.4±13.9 |
| Ni | 36.2±24.3 | 48.7±22.3 | 43.9±26.4 |
| Cu | 61.5±11.6 | 29.6±23.4 | 46.5±23.7 |
| Zn | 52.5±13 | 64±15.4 | 28.4±20.7 |
| Ga | 69.6±4.3 | 76.9±11.6 | 26.4±28.4 |
| As | 36.9±10.5 | 26±12.5 | 24.7±12 |
| Rb | 50.7±16.7 | 29.2±14 | 8.79±12.7 |
| Sr | 47.3±11.5 | 61.8±9.4 | 17±20.1 |
| Y | 64.4±3.8 | 91±5 | 73.2±19.9 |
| Zr | 82.3±5.8 | 93.7±8.6 | 91±8.21 |
| Nb | 82.7±4.2 | 93.9±4.3 | 73.4±24.4 |
| Mo | 62.9±15.1 | 60.4±26.1 | 20.5±27.7 |
| Cd | 53.4±18.5 | 48.3±20 | 37.1±25.3 |
| Sb | 31.4±9.5 | 6.6±10 | 10.5±14.5 |
| Cs | 32.2±16.8 | 42.8±17.5 | 17.2±17.3 |
| Ba | 51.4±10.9 | 61.2±10.8 | 21.1±22.4 |
| La | 73.6±3.3 | 81.5±16.4 | 56.4±35.4 |
| Ce | 70.4±3.3 | 86.7±10.6 | 72.8±22.1 |
| Pr | 60.3±12.2 | 89.3±9.4 | 79.4±17.9 |
| Nd | 66.3±3.5 | 87.7±11.1 | 78.9±15 |
| Sm | 49.6±24.9 | 82.3±14 | 70.5±28.4 |
| Eu | 63.9±4.2 | 76.4±19.2 | 51.9±27.5 |
| Gd | 54±18.4 | 77.1±22.5 | 77.6±15.3 |

| Parameter | Peat porewaters | Lakes | Rivers |
|-----------|-----------------|-----------|-----------|
| Tb | 67.7±5.9 | 82.7±16.3 | 78.5±19.2 |
| Dy | 61±13.4 | 84.3±12.9 | 76.9±18.3 |
| Ho | 63.9±3.5 | 81.6±18 | 70.2±28.3 |
| Er | 62.4±4 | 81±15 | 75.7±20.4 |
| Tm | 59.9±3.9 | 75.3±21.6 | 71.5±18.9 |
| Yb | 59±4 | 83.1±11.2 | 71.1±28 |
| Lu | 56.9±5.3 | 74.6±15.2 | 73.5±17.3 |
| Hf | 75.3±6.2 | 72.7±22.2 | 73.2±24.6 |
| Tl | 25.5±5.1 | 55.2±21.3 | 41.7±24.6 |
| Pb | 65.4±13 | 63.7±23.5 | 42.9±28.5 |
| Th | 90.2±2.7 | 94.2±3.6 | 88.9±11.5 |
| U | 63.2±12.9 | 66.9±18.7 | 58.5±32.6 |