**Supplementary information**

# Toxicity assessment of coal ash after 50 years of weathering: integration of multielement analysis and biological endpoints

Petrović, M.[1], Vidaković-Cifrek, Ž.[2], Medunić, G.[2], Fiket, Ž.[1*]

Ruđer Bošković Institute, Bijenička cesta 54, 10000 Zagreb, Croatia

Faculty of Science, University of Zagreb, Horvatovac 102a, 10000 Zagreb, Croatia

* Corresponding author:

E-mail address: zeljka.fiket@irb.hr

Contents: 10 Tables, 1 Figure

**Table S1.** pH of eluates before and after pH adjustment.

| Landfill | Sample | Type | Initial pH | pH after correction |
|---|---|---|---|---|
| Plaški (LP) | LP3 | Bare | 8.3 | 6.8 |
| | LP10 | Bare | 7.3 | 6.9 |
| | LP1 | Veg. | 6.5 | - |
| | LP5 | Veg. | 6.5 | - |
| | LP8 | Soil | 7.7 | 6.8 |
| | LP9 | Soil | 6.8 | - |
| Štrmac (LŠ) | LŠ8 | Bare | 13.5 | 6.8 |
| | LŠ11 | Bare | 13.2 | 6.7 |
| | LŠ5 | Veg. | 8.1 | 6.9 |
| | LŠ4 | Veg. | 7.4 | 6.7 |
| | LŠ1 | Soil | 8.1 | 6.9 |
| | LŠ7 | Soil | 6.7 | - |
| Unweathered CCR | FA | Fly ash | 11.9 | 6.5 |
| | BA | Bottom ash | 13.1 | 6.9 |

**Table S2.** Total concentration of major oxides measured in weathered coal ash and soil samples from the Štrmac locality (wt%).

| | $Al_2O_3$ | CaO | $Fe_2O_3$ | $K_2O$ | MgO | MnO | $Na_2O$ | $P_2O_5$ | $SO_3$ | $TiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Soil samples | | | | | | | | | | |
| $LŠ1_1$ | 9.68 | 13.6 | 4.17 | 1.40 | 1.41 | 0.17 | 0.50 | 0.14 | 0.25 | 0.61 |
| $LŠ1_2$ | 8.35 | 18.1 | 4.95 | 1.31 | 1.23 | 0.16 | 0.45 | 0.11 | 0.42 | 0.52 |
| $LŠ1_3$ | 8.82 | 16.8 | 5.51 | 1.15 | 1.08 | 0.15 | 0.39 | 0.11 | 0.30 | 0.53 |
| $LŠ2_1$ | 8.07 | 8.00 | 3.19 | 0.84 | 0.70 | 0.13 | 0.27 | 0.13 | 0.50 | 0.56 |
| $LŠ2_2$ | 8.60 | 6.66 | 3.41 | 0.77 | 0.68 | 0.13 | 0.25 | 0.12 | 0.39 | 0.61 |
| LŠ7 | 7.23 | 19.6 | 10.8 | 0.07 | 1.89 | 0.03 | 0.10 | 0.06 | 32.2 | 0.35 |
| Bare weathered ash | | | | | | | | | | |
| $LŠ8_1$ | 3.86 | 33.5 | 2.25 | 0.06 | 2.55 | 0.01 | 0.07 | 0.03 | 10.4 | 0.21 |
| $LŠ8_2$ | 3.17 | 32.4 | 1.60 | 0.07 | 2.01 | 0.01 | 0.06 | 0.02 | 11.6 | 0.18 |
| $LŠ8_3$ | 3.01 | 33.3 | 1.65 | 0.07 | 1.96 | 0.01 | 0.06 | 0.02 | 13.0 | 0.16 |
| $LŠ9_1$ | 3.01 | 28.6 | 2.22 | 0.06 | 1.79 | 0.01 | 0.06 | 0.02 | 15.3 | 0.16 |
| $LŠ9_2$ | 2.84 | 33.7 | 1.86 | 0.05 | 1.75 | 0.01 | 0.04 | 0.02 | 15.6 | 0.16 |
| $LŠ9_3$ | 2.80 | 30.7 | 1.80 | 0.04 | 2.07 | 0.01 | 0.03 | 0.02 | 12.2 | 0.15 |
| $LŠ10_1$ | 3.24 | 34.8 | 1.89 | 0.05 | 2.06 | 0.01 | 0.05 | 0.02 | 12.9 | 0.17 |
| $LŠ10_2$ | 3.27 | 32.7 | 1.96 | 0.06 | 2.03 | 0.01 | 0.07 | 0.02 | 14.6 | 0.18 |
| $LŠ10_3$ | 3.63 | 33.7 | 2.14 | 0.06 | 2.04 | 0.01 | 0.07 | 0.02 | 14.4 | 0.19 |
| $LŠ11_1$ | 4.61 | 30.5 | 3.00 | 0.06 | 5.31 | 0.01 | 0.09 | 0.03 | 11.0 | 0.26 |
| $LŠ11_2$ | 3.30 | 33.9 | 2.17 | 0.05 | 2.84 | 0.01 | 0.07 | 0.03 | 14.2 | 0.19 |
| $LŠ11_3$ | 3.37 | 36.4 | 2.22 | 0.07 | 2.56 | 0.01 | 0.08 | 0.03 | 10.7 | 0.21 |
| Weathered ash with vegetation | | | | | | | | | | |
| $LŠ3_1$ | 2.70 | 43.4 | 1.36 | 0.06 | 0.68 | 0.01 | 0.04 | 0.03 | 2.74 | 0.15 |
| $LŠ3_2$ | 3.46 | 43.5 | 1.75 | 0.04 | 0.93 | 0.01 | 0.01 | 0.02 | 1.60 | 0.21 |
| $LŠ3_3$ | 3.34 | 44.4 | 1.72 | 0.04 | 0.99 | 0.01 | 0.01 | 0.03 | 1.38 | 0.21 |
| $LŠ4_1$ | 2.61 | 40.7 | 1.70 | 0.07 | 0.91 | 0.01 | 0.02 | 0.03 | 4.03 | 0.15 |
| $LŠ4_2$ | 2.05 | 45.9 | 1.40 | 0.04 | 0.93 | 0.01 | 0.02 | 0.02 | 1.87 | 0.12 |
| $LŠ4_3$ | 2.73 | 44.8 | 1.67 | 0.06 | 1.16 | 0.01 | 0.03 | 0.03 | 1.36 | 0.15 |
| $LŠ5_1$ | 3.90 | 30.7 | 2.29 | 0.38 | 1.29 | 0.05 | 0.29 | 0.22 | 2.86 | 0.20 |
| $LŠ5_2$ | 3.55 | 33.6 | 2.14 | 0.33 | 1.23 | 0.06 | 0.26 | 0.20 | 2.40 | 0.20 |
| $LŠ5_3$ | 4.13 | 31.2 | 4.00 | 0.33 | 1.45 | 0.06 | 0.26 | 0.22 | 2.91 | 0.22 |
| $LŠ6_1$ | 2.22 | 42.3 | 1.70 | 0.05 | 1.83 | 0.01 | 0.05 | 0.06 | 3.54 | 0.12 |
| $LŠ6_2$ | 2.38 | 39.1 | 1.76 | 0.06 | 1.82 | 0.01 | 0.05 | 0.05 | 3.93 | 0.13 |
| $LŠ6_3$ | 2.30 | 40.7 | 1.64 | 0.06 | 1.67 | 0.01 | 0.05 | 0.04 | 3.48 | 0.12 |

**Table S3.** Total concentration of major oxides measured in weathered coal ash and soil samples from the Plaški locality (wt%).

| | $Al_2O_3$ | CaO | $Fe_2O_3$ | $K_2O$ | MgO | MnO | $Na_2O$ | $P_2O_5$ | $SO_3$ | $TiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Soil samples | | | | | | | | | | |
| $LP8_1$ | 13.1 | 10.8 | 6.53 | 0.87 | 1.71 | 0.04 | 0.18 | 0.09 | 1.51 | 0.50 |
| $LP8_2$ | 12.6 | 10.8 | 7.14 | 0.87 | 1.31 | 0.12 | 0.24 | 0.10 | 1.46 | 0.49 |
| $LP8_3$ | 14.0 | 10.7 | 6.90 | 1.01 | 1.64 | 0.06 | 0.25 | 0.12 | 1.32 | 0.53 |
| LP9 | 16.1 | 8.76 | 7.50 | 1.07 | 1.69 | 0.04 | 0.20 | 0.09 | 1.57 | 0.58 |
| Bare weathered ash | | | | | | | | | | |
| $LP10_1$ | 9.99 | 25.9 | 5.39 | 0.45 | 1.72 | 0.03 | 0.26 | 0.16 | 1.33 | 0.37 |
| LP11 | 12.0 | 20.1 | 5.34 | 0.51 | 1.55 | 0.02 | 0.10 | 0.15 | 1.63 | 0.45 |
| $LP3_1$ | 11.4 | 18.7 | 8.29 | 0.68 | 2.57 | 0.05 | 0.40 | 0.12 | 3.83 | 0.43 |
| $LP3_2$ | 8.18 | 18.0 | 5.90 | 0.47 | 1.82 | 0.03 | 0.25 | 0.09 | 4.24 | 0.33 |
| $LP3_3$ | 10.8 | 17.5 | 7.39 | 0.82 | 2.31 | 0.05 | 0.39 | 0.10 | 3.74 | 0.42 |
| $LP3_4$ | 9.15 | 25.4 | 6.32 | 0.50 | 2.18 | 0.04 | 0.41 | 0.11 | 3.70 | 0.39 |
| $LP7_1$ | 8.36 | 23.4 | 5.06 | 0.48 | 1.51 | 0.03 | 0.23 | 0.10 | 1.56 | 0.34 |
| $LP7_1$ | 9.87 | 21.4 | 4.86 | 0.53 | 1.76 | 0.03 | 0.23 | 0.08 | 1.35 | 0.36 |
| $LP7_2$ | 9.14 | 24.9 | 4.81 | 0.42 | 1.58 | 0.02 | 0.17 | 0.08 | 1.21 | 0.34 |
| $LP7_3$ | 9.58 | 28.7 | 5.28 | 0.47 | 1.79 | 0.03 | 0.23 | 0.10 | 1.27 | 0.37 |
| Weathered ash with vegetation (**in between – a bare sample with few pioneer plants*) | | | | | | | | | | |
| $LP1_2$* | 11.7 | 22.5 | 7.50 | 0.66 | 2.39 | 0.04 | 0.25 | 0.13 | 1.29 | 0.47 |
| $LP1_5$* | 11.3 | 21.6 | 7.37 | 0.63 | 2.25 | 0.04 | 0.25 | 0.12 | 1.13 | 0.45 |
| $LP1_6$* | 12.6 | 21.1 | 7.18 | 0.72 | 2.32 | 0.04 | 0.27 | 0.13 | 1.14 | 0.48 |
| $LP4_1$ | 12.3 | 17.8 | 7.14 | 0.71 | 1.86 | 0.03 | 0.17 | 0.13 | 1.01 | 0.46 |
| $LP4_2$ | 10.8 | 23.5 | 5.20 | 0.48 | 1.52 | 0.03 | 0.13 | 0.09 | 1.24 | 0.38 |
| $LP4_3$ | 11.0 | 20.5 | 5.86 | 0.52 | 1.64 | 0.02 | 0.19 | 0.09 | 1.15 | 0.42 |
| $LP4_4$ | 10.9 | 19.6 | 6.04 | 0.51 | 1.72 | 0.03 | 0.17 | 0.11 | 1.15 | 0.43 |
| $LP5_2$ | 14.1 | 18.1 | 6.47 | 0.65 | 1.62 | 0.03 | 0.13 | 0.10 | 1.00 | 0.50 |
| $LP5_3$ | 14.2 | 18.9 | 7.12 | 0.64 | 1.77 | 0.03 | 0.13 | 0.13 | 1.13 | 0.50 |
| $LP5_4$ | 13.2 | 18.3 | 6.83 | 0.66 | 1.72 | 0.03 | 0.12 | 0.10 | 1.03 | 0.49 |
| $LP5_5$ | 13.6 | 19.3 | 6.73 | 0.62 | 1.65 | 0.04 | 0.11 | 0.10 | 1.09 | 0.49 |
| $LP6_1$ | 14.1 | 13.3 | 6.75 | 0.85 | 1.57 | 0.03 | 0.15 | 0.14 | 0.97 | 0.52 |
| $LP6_2$ | 14.1 | 17.0 | 6.95 | 0.75 | 1.72 | 0.03 | 0.14 | 0.12 | 0.98 | 0.51 |
| $LP6_3$ | 11.3 | 20.6 | 6.35 | 0.51 | 1.61 | 0.03 | 0.12 | 0.10 | 1.32 | 0.45 |
| $LP6_4$ | 13.5 | 21.0 | 6.76 | 0.59 | 1.75 | 0.03 | 0.14 | 0.11 | 1.10 | 0.51 |

**Table S4.** Total concentration of trace elements measured in weathered coal ash and soil samples from the Štrmac locality (mg $kg^{-1}$).

| | Essential micronutrients | | | | Non-essential and beneficial | | | | | | | | | | Non-essential and toxic | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cu | Mo | Ni | Zn | Ba | Ce | Co | Cs | Li | Rb | Sc | Se | Sr | V | As | Be | Bi | Cd | Cr | Pb | Sb | Sn | Tl | U |
| Limit of detection (LOD) | | | | | | | | | | | | | | | | | | | | | | | | |
| | 0.5 | 0.15 | 0.6 | 2 | 0.5 | 0.002 | 0.05 | 0.002 | 0.15 | 0.05 | 0.6 | 0.05 | 0.6 | 0.05 | 0.5 | 0.01 | 0.002 | 0.05 | 0.5 | 0.5 | 0.15 | 0.01 | 0.05 | 0.05 |
| Soil samples | | | | | | | | | | | | | | | | | | | | | | | | |
| $LŠ1_1$ | 74.8 | 1.52 | 101 | 108 | 334 | 56.4 | 19.8 | 6.34 | 46.4 | 103 | 11.2 | 10.3 | 251 | 131 | 7.38 | 1.68 | 1.88 | 0.22 | 142 | 29.1 | 0.93 | 3.88 | 0.61 | 3.89 |
| $LŠ1_2$ | 45.4 | 2.39 | 94.9 | 165 | 320 | 50.6 | 18.6 | 5.39 | 40.7 | 87.1 | 9.48 | 49.8 | 260 | 122 | 8.50 | 1.44 | 0.40 | 0.30 | 128 | 38.3 | 1.52 | 3.61 | 0.55 | 3.81 |
| $LŠ1_3$ | 48.8 | 2.59 | 92.4 | 141 | 303 | 55.1 | 18.5 | 5.98 | 43.7 | 89.3 | 9.60 | 23.3 | 282 | 135 | 14.6 | 1.73 | 0.43 | 0.51 | 137 | 63.0 | 1.47 | 3.75 | 0.71 | 3.41 |
| $LŠ2_1$ | 308 | 3.66 | 60.4 | 540 | 234 | 67.8 | 15.1 | 5.15 | 37.3 | 70.6 | 8.56 | 64.1 | 133 | 147 | 11.6 | 1.81 | 0.49 | 1.31 | 110 | 66.5 | 1.50 | 7.38 | 0.98 | 4.17 |
| $LŠ2_2$ | 360 | 3.53 | 67.6 | 510 | 240 | 69.7 | 15.5 | 5.48 | 38.9 | 73.6 | 8.97 | 5.44 | 119 | 153 | 12.6 | 1.95 | 0.53 | 1.16 | 117 | 70.2 | 1.78 | 7.13 | 1.02 | 3.67 |
| LŠ7 | 130 | 88.7 | 302 | 369 | 158 | 69.7 | 40.9 | 0.43 | 43.7 | 7.99 | 12.5 | 8.23 | 850 | 602 | 115 | 4.45 | 0.18 | 8.20 | 156 | 38.9 | 17.8 | 8.26 | 0.83 | 107 |
| Bare weathered ash | | | | | | | | | | | | | | | | | | | | | | | | |
| $LŠ8_1$ | 163 | 41.8 | 59.0 | 15.8 | 172 | 25.2 | 5.95 | 0.62 | 21.7 | 3.54 | 5.96 | 10.6 | 580 | 216 | 6.82 | 1.48 | 0.05 | bdl | 121 | 5.14 | 0.43 | 1.59 | 0.11 | 36.7 |
| $LŠ8_2$ | 67.0 | 30.7 | 44.8 | 24.3 | 97.3 | 20.4 | 4.78 | 0.77 | 25. | 4.00 | 4.87 | 10.2 | 604 | 154 | 5.02 | 1.24 | 0.03 | bdl | 98.3 | 3.52 | 0.45 | 1.33 | 0.11 | 23.9 |
| $LŠ8_3$ | 188 | 33.6 | 45.8 | 11.1 | 105 | 21.4 | 4.74 | 0.74 | 20.6 | 3.93 | 4.86 | 10.0 | 558 | 154 | 6.21 | 1.28 | 0.03 | bdl | 88.1 | 3.62 | 0.42 | 1.16 | 0.11 | 25.9 |
| $LŠ9_1$ | 47.7 | 36.3 | 55.6 | 21.1 | 100 | 20.2 | 5.54 | 0.62 | 20.6 | 3.53 | 4.76 | 16.6 | 650 | 231 | 14.6 | 1.15 | 0.10 | 0.53 | 91.4 | 6.61 | 0.78 | 1.64 | 0.75 | 44.4 |
| $LŠ9_2$ | 74.9 | 40.5 | 50.5 | 19.7 | 93.9 | 20.1 | 4.87 | 0.55 | 16.6 | 3.34 | 4.71 | 14.4 | 697 | 223 | 7.90 | 1.16 | 0.03 | bdl | 88.8 | 2.95 | 0.39 | 1.00 | 0.14 | 44.2 |
| $LŠ9_3$ | 45.3 | 37.5 | 50.7 | 11.0 | 90.1 | 17.8 | 5.02 | 0.42 | 13.2 | 2.58 | 4.21 | 9.49 | 543 | 190 | 6.12 | 1.00 | 0.02 | bdl | 76.0 | 3.72 | 0.35 | 0.92 | 0.11 | 40.7 |
| $LŠ10_1$ | 57.0 | 35.6 | 45.3 | 8.92 | 101 | 22.2 | 5.09 | 0.54 | 21.0 | 3.12 | 5.13 | 12.0 | 689 | 193 | 7.07 | 1.08 | 0.03 | bdl | 96.5 | 2.43 | 0.43 | 1.02 | 0.15 | 30.9 |
| $LŠ10_2$ | 65.0 | 32.7 | 47.8 | 15.0 | 129 | 23.0 | 5.33 | 0.59 | 23.9 | 3.42 | 5.14 | 33.2 | 778 | 183 | 6.60 | 1.12 | 0.03 | bdl | 97.6 | 4.75 | 0.51 | 1.25 | 0.13 | 30.7 |
| $LŠ10_3$ | 44.3 | 36.9 | 54.8 | 16.4 | 132 | 25.2 | 5.85 | 0.61 | 25.0 | 3.55 | 5.85 | 13.1 | 869 | 217 | 7.32 | 1.23 | 0.04 | bdl | 101 | 4.16 | 0.57 | 1.24 | 0.13 | 34.1 |
| $LŠ11_1$ | 67.8 | 56.0 | 84.3 | 15.3 | 105 | 36.7 | 7.38 | 0.58 | 29.8 | 3.63 | 7.99 | 10.2 | 964 | 282 | 11.0 | 1.70 | 0.04 | 0.30 | 127 | 6.40 | 0.55 | 1.47 | 0.19 | 71.6 |
| $LŠ11_2$ | 70.2 | 38.8 | 65.8 | 23.9 | 115 | 26.9 | 5.49 | 0.52 | 20.5 | 3.01 | 6.17 | 6.09 | 997 | 227 | 7.79 | 1.31 | 0.03 | 0.08 | 100 | 6.56 | 0.40 | 1.23 | 0.13 | 56.4 |
| $LŠ11_3$ | 69.4 | 33.0 | 64.3 | 16.7 | 90.3 | 28.2 | 5.36 | 0.54 | 22.7 | 3.50 | 6.38 | 63.5 | 1115 | 220 | 7.45 | 1.30 | 0.03 | 0.05 | 98.8 | 6.48 | 0.40 | 1.23 | 0.12 | 55.2 |
| Weathered ash with vegetation | | | | | | | | | | | | | | | | | | | | | | | | |
| $LŠ3_1$ | 63.7 | 3.25 | 42.2 | 49.3 | 43.8 | 12.1 | 4.17 | 0.45 | 8.91 | 2.83 | 2.87 | 5.91 | 732 | 205 | 5.22 | 0.73 | 0.04 | 0.45 | 72.6 | 12.3 | 0.53 | 2.35 | 0.12 | 14.8 |
| $LŠ3_2$ | 67.6 | 3.10 | 42.9 | 41.7 | 41.4 | 13.4 | 4.34 | 0.51 | 9.54 | 3.12 | 3.02 | 7.14 | 710 | 209 | 4.87 | 0.77 | 0.04 | 0.42 | 79.2 | 10.9 | 0.55 | 2.06 | 0.13 | 16.6 |
| $LŠ3_3$ | 63.8 | 2.88 | 40.9 | 37.1 | 42.6 | 14.1 | 4.18 | 0.51 | 9.35 | 3.18 | 3.06 | 7.85 | 725 | 205 | 4.97 | 0.75 | 0.04 | 0.37 | 80.1 | 10.8 | 0.50 | 2.45 | 0.15 | 20.0 |
| $LŠ4_1$ | 511 | 5.80 | 48.2 | 1860 | 228 | 24.1 | 6.80 | 1.76 | 17.9 | 24.5 | 4.70 | 5.61 | 434 | 105 | 8.82 | 0.96 | 0.35 | 1.15 | 76.1 | 140 | 2.22 | 14.9 | 0.38 | 9.56 |
| $LŠ4_2$ | 734 | 6.14 | 46.9 | 1691 | 215 | 22.5 | 6.88 | 1.55 | 18.1 | 22.1 | 4.33 | 3.67 | 426 | 103 | 8.30 | 0.95 | 0.34 | 1.25 | 83.2 | 98.0 | 2.35 | 32.3 | 0.34 | 10.4 |
| $LŠ4_3$ | 1822 | 8.90 | 60.8 | 2012 | 289 | 25.6 | 8.61 | 1.68 | 20.8 | 23.3 | 5.05 | 5.38 | 510 | 136 | 15.2 | 1.17 | 0.34 | 1.22 | 82.7 | 142 | 7.11 | 38.4 | 0.36 | 13.1 |
| $LŠ5_1$ | 25.4 | 24.1 | 52.2 | 48.8 | 42.3 | 16.3 | 5.59 | 0.45 | 13.7 | 4.17 | 3.33 | 48.8 | 363 | 86.4 | 18.3 | 0.80 | 0.20 | 1.00 | 48.0 | 14.4 | 1.37 | 2.08 | 0.53 | 14.4 |
| $LŠ5_2$ | 17.63 | 19.23 | 44.4 | 29.3 | 38.4 | 13.7 | 4.41 | 0.35 | 10.6 | 3.06 | 2.86 | 8.04 | 382 | 81.9 | 17.7 | 0.63 | 0.14 | 1.05 | 35.7 | 9.65 | 1.19 | 1.96 | 0.58 | 14.7 |
| $LŠ5_3$ | 21.19 | 22.48 | 53.4 | 143 | 46.4 | 17.0 | 5.29 | 0.61 | 14.2 | 3.60 | 3.46 | 8.33 | 413 | 101 | 21.7 | 0.72 | 0.17 | 2.26 | 43.0 | 14.6 | 1.53 | 1.67 | 1.55 | 18.1 |
| $LŠ6_1$ | 18.98 | 29.66 | 41.8 | 28.7 | 29.4 | 13.8 | 4.61 | 0.37 | 14.5 | 3.54 | 2.71 | 8.64 | 373 | 57.3 | 17.6 | 0.62 | 0.19 | 0.67 | 44.2 | 12.8 | 1.14 | 1.67 | 0.37 | 9.41 |
| $LŠ6_2$ | 47.53 | 32.90 | 50.1 | 29.0 | 27.9 | 17.0 | 5.92 | 0.31 | 17.4 | 2.29 | 3.26 | 8.17 | 352 | 62.0 | 21.6 | 0.71 | 0.26 | 0.68 | 54.7 | 14.2 | 1.45 | 1.80 | 0.39 | 11.7 |
| $LŠ6_3$ | 27.82 | 32.98 | 49.1 | 29.5 | 43.8 | 17.0 | 5.56 | 0.31 | 18.1 | 2.27 | 3.21 | 9.16 | 349 | 64.7 | 20.9 | 0.68 | 0.29 | 0.70 | 53.9 | 12.2 | 1.43 | 1.96 | 0.38 | 12.2 |

**Table S5.** Total concentration of trace elements measured in weathered coal ash and soil samples from the Plaški locality (mg kg$^{-1}$).

| | Essential micronutrients | | | | Non-essential and beneficial | | | | | | | | | | Non-essential and toxic | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cu | Mo | Ni | Zn | Ba | Ce | Co | Cs | Li | Rb | Sc | Se | Sr | V | As | Be | Bi | Cd | Cr | Pb | Sb | Sn | Tl | U |
| Soil samples | | | | | | | | | | | | | | | | | | | | | | | | |
| $LP8_1$ | 117 | 17.2 | 552 | 96.1 | 306 | 41.8 | 26.4 | 13.0 | 61.3 | 65.8 | 17.7 | 15.58 | 270 | 253 | 89.2 | 2.02 | 0.23 | 0.57 | 375 | 17.4 | 2.48 | 3.05 | 0.66 | 30.1 |
| $LP8_2$ | 91.5 | 14.2 | 410 | 61.9 | 322 | 39.5 | 23.8 | 11.1 | 53.3 | 61.3 | 14.8 | 7.91 | 253 | 201 | 21.1 | 2.00 | 0.10 | 0.28 | 273 | 9.29 | 1.87 | 1.58 | 0.33 | 23.6 |
| $LP8_3$ | 92.9 | 12.8 | 325 | 60.3 | 415 | 41.8 | 22.7 | 13.2 | 58.7 | 70.1 | 17.5 | 2.87 | 261 | 218 | 21.1 | 2.04 | 0.09 | 0.26 | 296 | 8.33 | 2.10 | 1.66 | 0.31 | 20.2 |
| LP9 | 128 | 12.4 | 806 | 75.1 | 273 | 46.9 | 47.0 | 19.1 | 58.3 | 74.3 | 19.5 | 2.22 | 240 | 223 | 37.0 | 2.38 | 0.14 | 0.35 | 488 | 13.8 | 2.10 | 2.91 | 0.47 | 17.3 |
| Bare weathered ash | | | | | | | | | | | | | | | | | | | | | | | | |
| $LP10_1$ | 84.4 | 27.2 | 640 | 41.4 | 302 | 29.5 | 34.2 | 10.9 | 36.9 | 45.6 | 15.1 | 17.05 | 546 | 218 | 22.4 | 1.65 | 0.07 | 0.20 | 433 | 4.98 | 1.17 | 2.32 | 0.14 | 30.5 |
| LP11 | 120 | 38.8 | 334 | 60.1 | 223 | 38.7 | 20.0 | 9.74 | 50.9 | 49.7 | 14.2 | 6.18 | 446 | 287 | 26.8 | 1.61 | 0.12 | 0.39 | 275 | 10.7 | 1.60 | 1.96 | 0.42 | 64.0 |
| $LP3_1$ | 116 | 54.8 | 1074 | 70.8 | 450 | 36.9 | 40.0 | 15.6 | 56.1 | 48.0 | 17.6 | 4.36 | 573 | 261 | 107 | 1.75 | 3.19 | 0.46 | 633 | 14.5 | 2.07 | 3.15 | 0.46 | 64.4 |
| $LP3_2$ | 77.9 | 40.4 | 797 | 66.0 | 376 | 25.2 | 30.0 | 6.03 | 33.7 | 23.8 | 13.1 | 1.73 | 376 | 228 | 64.8 | 1.15 | 0.14 | 0.37 | 464 | 10.0 | 2.01 | 2.09 | 0.32 | 43.2 |
| $LP3_3$ | 107 | 30.9 | 1133 | 75.3 | 261 | 30.0 | 40.5 | 9.66 | 51.5 | 56.0 | 17.4 | 2.47 | 383 | 224 | 81.0 | 1.37 | 0.30 | 0.38 | 689 | 14.7 | 1.97 | 2.30 | 0.38 | 34.0 |
| $LP3_4$ | 101 | 51.4 | 607 | 53.3 | 284 | 26.0 | 28.7 | 5.67 | 39.5 | 31.1 | 13.8 | 1.92 | 648 | 254 | 56.0 | 1.36 | 0.11 | 0.35 | 434 | 9.70 | 1.47 | 2.24 | 0.20 | 41.8 |
| $LP7_1$ | 79.1 | 25.1 | 422 | 42.9 | 219 | 28.5 | 22.1 | 7.44 | 37.3 | 41.5 | 10.8 | 2.84 | 469 | 238 | 23.0 | 1.19 | 0.07 | 0.22 | 272 | 8.19 | 1.53 | 1.25 | 0.21 | 45.1 |
| $LP7_1$ | 74.3 | 29.1 | 407 | 52.2 | 228 | 30.6 | 22.7 | 9.33 | 37.9 | 46.4 | 12.7 | 6.70 | 439 | 249 | 21.0 | 1.30 | 0.09 | 0.26 | 293 | 11.0 | 1.12 | 1.31 | 0.21 | 47.5 |
| $LP7_2$ | 75.9 | 30.8 | 390 | 49.3 | 213 | 28.9 | 22.5 | 6.74 | 31.6 | 38.1 | 11.9 | 2.38 | 399 | 247 | 20.1 | 1.32 | 0.17 | 0.19 | 285 | 6.49 | 1.19 | 2.55 | 0.19 | 49.1 |
| $LP7_3$ | 79.2 | 35.2 | 442 | 41.3 | 239 | 30.9 | 24.7 | 7.85 | 34.4 | 42.0 | 13.0 | 2.17 | 492 | 245 | 20.1 | 1.33 | 0.12 | 0.19 | 300 | 15.3 | 1.31 | 2.38 | 0.17 | 50.8 |
| Weathered ash with vegetation (**in between – a bare sample with few pioneer plants*) | | | | | | | | | | | | | | | | | | | | | | | | |
| $LP1_2$* | 112 | 36.1 | 786 | 73.1 | 332 | 38.2 | 34.2 | 10.2 | 49.6 | 48.9 | 15.8 | 3.29 | 506 | 306 | 66.5 | 1.70 | 0.14 | 0.43 | 529 | 12.9 | 1.89 | 1.71 | 0.38 | 52.9 |
| $LP1_5$* | 103 | 37.8 | 825 | 59.2 | 347 | 36.1 | 35.3 | 10.6 | 47.3 | 49.4 | 15.8 | 3.28 | 489 | 288 | 66.0 | 1.71 | 0.26 | 0.38 | 551 | 13.9 | 1.81 | 1.71 | 0.38 | 51.8 |
| $LP1_6$* | 108 | 35.4 | 818 | 127.8 | 348 | 39.9 | 35.0 | 11.8 | 52.6 | 55.4 | 16.0 | 2.39 | 496 | 300 | 64.4 | 1.75 | 0.16 | 0.47 | 558 | 15.7 | 1.98 | 2.09 | 0.42 | 55.4 |
| $LP4_1$ | 111 | 31.3 | 563 | 69.9 | 254 | 38.3 | 30.1 | 12.2 | 45.0 | 58.3 | 16.1 | 3.92 | 356 | 275 | 34.8 | 1.71 | 0.13 | 0.36 | 393 | 15.1 | 1.65 | 2.86 | 0.45 | 56.5 |
| $LP4_2$ | 92.9 | 26.0 | 435 | 60.1 | 225 | 31.7 | 22.3 | 9.66 | 38.4 | 41.0 | 13.7 | 3.39 | 404 | 290 | 31.7 | 1.35 | 0.10 | 0.34 | 346 | 15.7 | 1.54 | 2.81 | 0.47 | 44.8 |
| $LP4_3$ | 100 | 29.9 | 441 | 97.2 | 222 | 33.2 | 24.2 | 8.98 | 38.7 | 41.9 | 12.6 | 3.17 | 378 | 313 | 23.7 | 1.44 | 0.10 | 0.26 | 330 | 9.08 | 1.35 | 1.51 | 0.34 | 48.7 |
| $LP4_4$ | 91.2 | 30.1 | 458 | 41.8 | 234 | 34.2 | 25.0 | 10.0 | 39.7 | 44.7 | 12.8 | 3.55 | 380 | 294 | 26.0 | 1.58 | 0.07 | 0.30 | 341 | 9.62 | 1.52 | 1.39 | 0.40 | 50.8 |
| $LP5_2$ | 156 | 24.3 | 602 | 60.2 | 236 | 43.5 | 26.5 | 14.1 | 52.7 | 55.9 | 17.0 | 1.61 | 356 | 284 | 41.2 | 2.03 | 0.11 | 0.41 | 384 | 15.0 | 1.98 | 1.92 | 0.43 | 37.7 |
| $LP5_3$ | 115 | 28.6 | 579 | 70.5 | 317 | 42.0 | 31.1 | 13.0 | 54.2 | 53.9 | 17.9 | 2.67 | 373 | 279 | 33.4 | 1.97 | 0.10 | 0.33 | 392 | 10.8 | 1.97 | 2.80 | 0.35 | 46.3 |
| $LP5_4$ | 112 | 29.0 | 535 | 51.6 | 232 | 40.4 | 27.4 | 13.1 | 52.3 | 54.4 | 15.0 | 3.16 | 368 | 273 | 36.5 | 1.93 | 2.63 | 0.38 | 392 | 10.5 | 2.03 | 1.66 | 0.35 | 45.3 |
| $LP5_5$ | 119 | 24.3 | 531 | 62.1 | 234 | 40.6 | 27.7 | 13.3 | 51.9 | 54.3 | 17.9 | 2.24 | 354 | 279 | 41.5 | 1.90 | 0.14 | 0.32 | 392 | 11.6 | 2.16 | 2.22 | 0.38 | 41.9 |
| $LP6_1$ | 125 | 24.0 | 535 | 77.2 | 261 | 41.8 | 28.5 | 15.5 | 55.3 | 69.4 | 17.0 | 2.42 | 300 | 252 | 41.0 | 1.91 | 0.19 | 0.55 | 408 | 20.7 | 1.93 | 2.02 | 0.57 | 37.2 |
| $LP6_2$ | 132 | 31.3 | 510 | 54.0 | 229 | 40.9 | 27.3 | 14.1 | 55.4 | 61.2 | 16.3 | 3.77 | 339 | 272 | 37.7 | 1.92 | 0.10 | 0.39 | 379 | 13.8 | 1.83 | 1.82 | 0.39 | 43.4 |
| $LP6_3$ | 108 | 31.2 | 511 | 46.5 | 211 | 36.2 | 26.4 | 9.55 | 42.6 | 40.9 | 13.7 | 4.24 | 359 | 274 | 32.3 | 1.61 | 0.10 | 0.36 | 362 | 9.35 | 1.28 | 1.45 | 0.32 | 49.8 |
| $LP6_4$ | 137 | 33.6 | 500 | 56.1 | 239 | 40.6 | 26.7 | 10.8 | 50.8 | 49.4 | 16.9 | 2.34 | 378 | 306 | 31.5 | 1.84 | 0.11 | 0.35 | 382 | 10.2 | 1.64 | 2.24 | 0.33 | 52.7 |
| Unweathered bottom and fly ash (*n.m. = not measured*) | | | | | | | | | | | | | | | | | | | | | | | | |
| BA | 56.5 | 29.9 | 75.9 | 31.7 | 47.5 | n.m. | 4.53 | 4.53 | 10.6 | 151 | n.m. | 2.73 | 946 | 523 | 7.68 | 0.52 | 0.06 | 0.17 | 129 | 2.07 | 1.48 | 1.07 | 0.13 | 106 |
| FA | 48.1 | 56.7 | 89.6 | 51.0 | 27.4 | n.m. | 5.20 | 5.20 | 18.5 | 860 | n.m. | 43.1 | 1353 | 727 | 24.2 | 0.99 | 0.24 | 1.12 | 162 | 17.2 | 2.38 | 1.99 | 1.75 | 137 |

| | LOD | Negative control | | Štrmac samples | | | | | | Plaški samples | | | | | | Unweathered | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | LŠ1 | LŠ7 | LŠ8 | LŠ11 | LŠ5 | LŠ4 | LP8 | LP9 | LP3 | LP10 | LP1 | LP5 | FA | BA |
| Essential nutrients | | | | | | | | | | | | | | | | | |
| Ca* | 0.002 | 96.6 | 100 | 40.0 | 617 | 443 | 992 | 29.8 | 43.6 | 30.8 | 28.9 | 407 | 58.2 | 42.2 | 27.9 | 639 | 1105 |
| Cu | 0.02 | 11.0 | 3.75 | 10.3 | bdl | 11.4 | 22.1 | 3.46 | 54.9 | 1.39 | 0.25 | 2.53 | 7.40 | 4.59 | 5.11 | 0.93 | 7.49 |
| Fe | 0.02 | 78.3 | 0.43 | 132 | 65.9 | 266 | 27.7 | 191 | 119 | 38.4 | 17.0 | 21.2 | 33.8 | 35.9 | 34.4 | 18.9 | 25.5 |
| K* | 0.002 | 2.95 | 3.00 | 3.82 | 0.87 | 7.30 | 2.17 | 0.55 | 86.1 | 1.43 | 1.01 | 14.2 | 6.30 | 3.23 | 4.45 | 118 | 13.9 |
| Mg* | 0.002 | 23.4 | 22.3 | 2.79 | 4.55 | 0.08 | 0.07 | 1.37 | 2.02 | 0.95 | 1.44 | 86.4 | 5.86 | 2.41 | 0.73 | 0.24 | 0.18 |
| Mn | 0.008 | 3.27 | 0.88 | 6.95 | 13.1 | 2.94 | 2.56 | 8.48 | 5.25 | 0.30 | 0.10 | 7.65 | 0.52 | 1.61 | bdl | bdl | 1.29 |
| Mo | 0.002 | 0.27 | 0.24 | 8.37 | 177 | 58.5 | 356 | 6.79 | 3.45 | 4.70 | 3.28 | 1235 | 68.5 | 24.90 | 6.75 | 447 | 481 |
| Ni | 0.02 | 15.2 | 0.58 | 42.4 | 42.2 | 27.9 | 32.9 | 35.8 | 132 | 13.7 | 11.4 | 36.4 | 22.3 | 33.9 | 15.0 | 17.1 | 29.1 |
| Zn | 0.03 | 334 | 253 | 40.1 | 10.9 | 5.37 | 176 | 8.25 | 97.4 | 42.8 | 0.69 | 11.3 | 11.3 | 22.6 | 10.2 | 8.70 | 281 |
| Non-essential and beneficial | | | | | | | | | | | | | | | | | |
| Ba | 0.002 | 70.2 | 59.1 | 23.8 | 27.5 | 93.6 | 150 | 9.60 | 40.2 | 3.32 | 2.01 | 20.9 | 9.72 | 5.84 | 1.74 | 46.8 | 167 |
| Co | 0.002 | 0.02 | 0.05 | 0.18 | 0.15 | 0.09 | 0.11 | 0.12 | 0.08 | 0.07 | 0.04 | 0.19 | 0.05 | 0.02 | 0.10 | bdl | 0.03 |
| Cs | 0.002 | bdl | bdl | 0.01 | bdl | 0.31 | 1.21 | bdl | 1.04 | 0.46 | 0.08 | 3.17 | 1.58 | 0.50 | 0.63 | 39.2 | 2.25 |
| Li | 0.003 | 1.39 | 1.12 | bdl | 14.6 | 3.35 | 24.0 | bdl | bdl | 4.44 | 5.76 | 126 | 42.7 | 13.3 | 4.76 | 129 | 76.4 |
| | 0.002 | | | | | | | | | | 0.03 | | | | | | |
| Na* | | 24.9 | 26.1 | 1.98 | 1.78 | 0.265 | 2.79 | 0.69 | 1.54 | 0.82 | | 61.6 | 1.18 | 2.53 | 0.12 | 580 | 93.4 |
| Rb | 0.002 | 0.58 | 0.54 | 1.42 | 2.22 | 1.51 | 13.6 | 0.74 | 10.9 | 7.51 | 3.07 | 39.7 | 27.7 | 10.4 | 8.20 | 360 | 23.6 |
| Se | 0.002 | 0.12 | 0.52 | 5.65 | 5.36 | 0.09 | 5.49 | 4.18 | 5.18 | 5.29 | bdl | 23.4 | 3.92 | 2.32 | 6.28 | 276 | 41.5 |
| Sr | 0.005 | 238 | 229 | 148 | 3865 | 1059 | 8261 | 57.5 | 158 | 73.8 | 51.2 | 1158 | 252 | 101 | 51.3 | 12780 | 9730 |
| Ti | 0.01 | 0.82 | 0.01 | 3.51 | 9.20 | 0.26 | 2.23 | 7.15 | 3.68 | 2.58 | bdl | 1.01 | 0.67 | 1.13 | 1.00 | bdl | 3.56 |
| V | 0.003 | 0.40 | 0.15 | 5.71 | 30.7 | 1.50 | 18.6 | 24.8 | 29.5 | 60.6 | 31.1 | 54.6 | 54.1 | 72.75 | 98.0 | 198 | 49.7 |
| Non-essential and toxic | | | | | | | | | | | | | | | | | |
| Al* | 0.002 | 4.22 | 0.002 | 6.89 | 13.4 | 2.10 | 5.21 | 16.0 | 10.5 | 0.59 | 0.83 | 0.04 | 0.66 | 4.38 | 0.81 | 1.35 | 0.18 |
| As | 0.005 | bdl | 0.13 | 0.88 | 1.02 | bdl | 0.03 | 3.98 | 1.64 | 19.2 | 7.74 | 18.1 | 5.32 | 15.2 | 62.5 | 0.84 | 0.38 |
| Be | 0.006 | 0.12 | bdl | 0.36 | 0.15 | bdl | 0.36 | bdl | 0.11 | 0.34 | 0.16 | 0.25 | 0.57 | 0.20 | 0.32 | 0.19 | 0.26 |
| Bi | 0.002 | 0.10 | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | 0.01 | bdl | bdl | bdl |
| Cd | 0.002 | 0.07 | 0.01 | 0.08 | 1.77 | 0.49 | 2.67 | 0.10 | 0.16 | 0.05 | 0.02 | 9.83 | 0.53 | 0.19 | 0.06 | 3.78 | 4.14 |
| Cr | 0.08 | 0.84 | 0.19 | 1.53 | 2.39 | 3.05 | 15.2 | 4.55 | 2.91 | 0.79 | 0.86 | 0.21 | 1.81 | 2.19 | 0.79 | 32.8 | 642 |
| Pb | 0.002 | 4.63 | 0.31 | 3.84 | 0.12 | 1.67 | 2.40 | 4.79 | 3.44 | 3.31 | 0.20 | 73.8 | 1.75 | 0.06 | 0.13 | 2.89 | 5.36 |
| Sb | 0.004 | 0.06 | 0.06 | 0.08 | 0.93 | bdl | bdl | 0.22 | 0.99 | 0.29 | 0.54 | 1.94 | 0.73 | 0.78 | 0.66 | 0.17 | bdl |
| Sn | 0.008 | 2.52 | 0.21 | 0.86 | 1.11 | 0.30 | 0.26 | 1.38 | 1.39 | 1.64 | bdl | 2.69 | 0.65 | 0.89 | 0.85 | 1.06 | 2.95 |
| Tl | 0.002 | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | 2.85 | bdl |
| U | 0.002 | 0.80 | 0.87 | 1.41 | 277 | 0.15 | 0.13 | 3.49 | 5.68 | 3.47 | 3.65 | 97.3 | 15.6 | 23.3 | 5.13 | 1.64 | 0.41 |

**Table S6.** Concentration of elements measured in negative control, selected weathered coal ash eluates from the Štrmac and Plaški locality and in unweathered fly and bottom ash samples (in µg/L or *mg/L). Note: *LOD = limit of detection; bdl = below the detection limit*

**Table S7.** Relative Mass Leached (%) of elements calculated for selected weathered coal ash eluates from the Štrmac and Plaški locality and in unweathered fly and bottom ash samples. Note: *bdl = below the detection limit; n.m. = not measured total concentrations.*

| | Štrmac samples | | | | | | Plaški samples | | | | | | Unweathered | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LŠ1 | LŠ7 | LŠ8 | LŠ11 | LŠ5 | LŠ4 | LP8 | LP9 | LP3 | LP10 | LP1 | LP5 | FA | BA |
| Essential nutrients | | | | | | | | | | | | | | |
| Ca | 0.41 | 4.39 | 1.85 | 4.55 | 0.10 | 0.20 | 0.40 | 0.46 | 3.04 | 0.31 | 0.26 | 0.22 | n.m. | n.m. |
| Cu | 0.14 | bdl | 0.07 | 0.33 | 0.14 | 0.11 | 0.01 | 0.01 | 0.02 | 0.09 | 0.04 | 0.03 | 0.02 | 0.13 |
| Fe | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| K | 0.33 | 1.60 | 13.5 | 4.18 | 0.97 | 27.4 | 0.20 | 0.12 | 2.49 | 1.68 | 0.59 | 0.83 | n.m. | n.m. |
| Mg | 0.33 | 0.40 | 0.01 | 0.01 | 0.25 | 0.26 | 0.09 | 0.14 | 5.57 | 0.57 | 0.17 | 0.08 | n.m. | n.m. |
| Mn | 0.01 | 0.07 | 0.04 | 0.03 | 0.08 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | bdl | 0.01 | 0.04 |
| Mo | 5.51 | 1.99 | 1.40 | 6.36 | 0.28 | 0.60 | 0.27 | 0.26 | 22.5 | 2.52 | 0.69 | 0.28 | 7.90 | 16.1 |
| Ni | 0.42 | 0.14 | 0.47 | 0.39 | 0.69 | 2.75 | 0.02 | 0.01 | 0.03 | 0.04 | 0.04 | 0.03 | 0.19 | 0.38 |
| Zn | 0.37 | 0.03 | 0.34 | 11.5 | 0.17 | 0.05 | 0.45 | 0.01 | 0.16 | 0.27 | 0.31 | 0.17 | 0.17 | 8.87 |
| Non-essential and beneficial | | | | | | | | | | | | | | |
| Ba | 0.07 | 0.17 | 0.54 | 1.43 | 0.23 | 0.18 | 0.01 | 0.01 | 0.05 | 0.03 | 0.02 | 0.01 | 1.70 | 3.51 |
| Co | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.05 | 0.01 | 0.01 | 0.01 | bdl | 0.07 |
| Cs | 0.01 | 0.01 | 0.50 | 2.08 | bdl | 0.59 | 0.04 | 0.01 | 0.20 | 0.15 | 0.05 | 0.05 | n.m. | n.m. |
| Li | bdl | 0.33 | 0.15 | 0.81 | bdl | bdl | 0.07 | 0.10 | 2.25 | 1.16 | 0.27 | 0.09 | 7.03 | 7.24 |
| Na | 0.54 | 2.46 | 0.50 | 4.30 | 5.07 | 0.72 | 0.60 | 0.02 | 20.5 | 0.62 | 1.37 | 0.13 | n.m. | n.m. |
| Rb | 0.01 | 0.28 | 0.43 | 3.76 | 0.18 | 0.44 | 0.12 | 0.04 | 0.83 | 0.61 | 0.21 | 0.15 | 0.42 | 0.16 |
| Se | 0.55 | 0.65 | 0.01 | 0.54 | 0.09 | 0.92 | 0.34 | bdl | 5.37 | 0.23 | 0.70 | 3.91 | 6.42 | 15.2 |
| Sr | 0.59 | 4.55 | 1.83 | 8.57 | 0.16 | 0.36 | 0.27 | 0.21 | 2.02 | 0.46 | 0.20 | 0.14 | 9.45 | 10.3 |
| Ti | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | bdl | 0.01 |
| V | 0.04 | 0.05 | 0.01 | 0.07 | 0.29 | 0.28 | 0.24 | 0.14 | 0.21 | 0.25 | 0.24 | 0.35 | 0.27 | 0.10 |
| Non-essential and toxic | | | | | | | | | | | | | | |
| Al | 0.13 | 0.35 | 0.10 | 0.21 | 1.15 | 0.51 | 0.01 | 0.01 | 0.01 | 0.01 | 0.07 | 0.01 | 0.10 | 0.02 |
| As | 0.12 | 0.01 | bdl | 0.01 | 0.22 | 0.19 | 0.22 | 0.21 | 0.17 | 0.24 | 0.23 | 1.52 | 0.04 | 0.05 |
| Be | 0.21 | 0.03 | bdl | 0.21 | bdl | 0.12 | 0.17 | 0.07 | 0.14 | 0.35 | 0.12 | 0.16 | 0.19 | 0.50 |
| Bi | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | 0.07 | bdl | 0.01 | bdl |
| Cd | 0.36 | 0.22 | bdl | 8.95 | 0.10 | 0.14 | 0.09 | 0.06 | 21.6 | 2.71 | 0.44 | 0.15 | 3.39 | 24.0 |
| Cr | 0.01 | 0.02 | 0.03 | 0.12 | 0.10 | 0.04 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.20 | 5.00 |
| Pb | 0.13 | 0.01 | 0.33 | 0.38 | 0.33 | 0.02 | 0.19 | 0.01 | 5.08 | 0.35 | 0.01 | 0.01 | 0.17 | 2.59 |
| Sb | 0.09 | 0.05 | bdl | bdl | 0.16 | 0.45 | 0.12 | 0.26 | 0.94 | 0.62 | 0.41 | 0.33 | 0.07 | bdl |
| Sn | 0.22 | 0.13 | 0.19 | 0.17 | 0.66 | 0.09 | 0.54 | bdl | 0.85 | 0.28 | 0.52 | 0.44 | 0.53 | 2.75 |
| Tl | bdl | 0.01 | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | bdl | 1.63 | bdl |
| U | 0.36 | 2.58 | 0.01 | 0.01 | 0.24 | 0.60 | 0.12 | 0.21 | 1.51 | 0.51 | 0.44 | 0.14 | 0.01 | 0.01 |

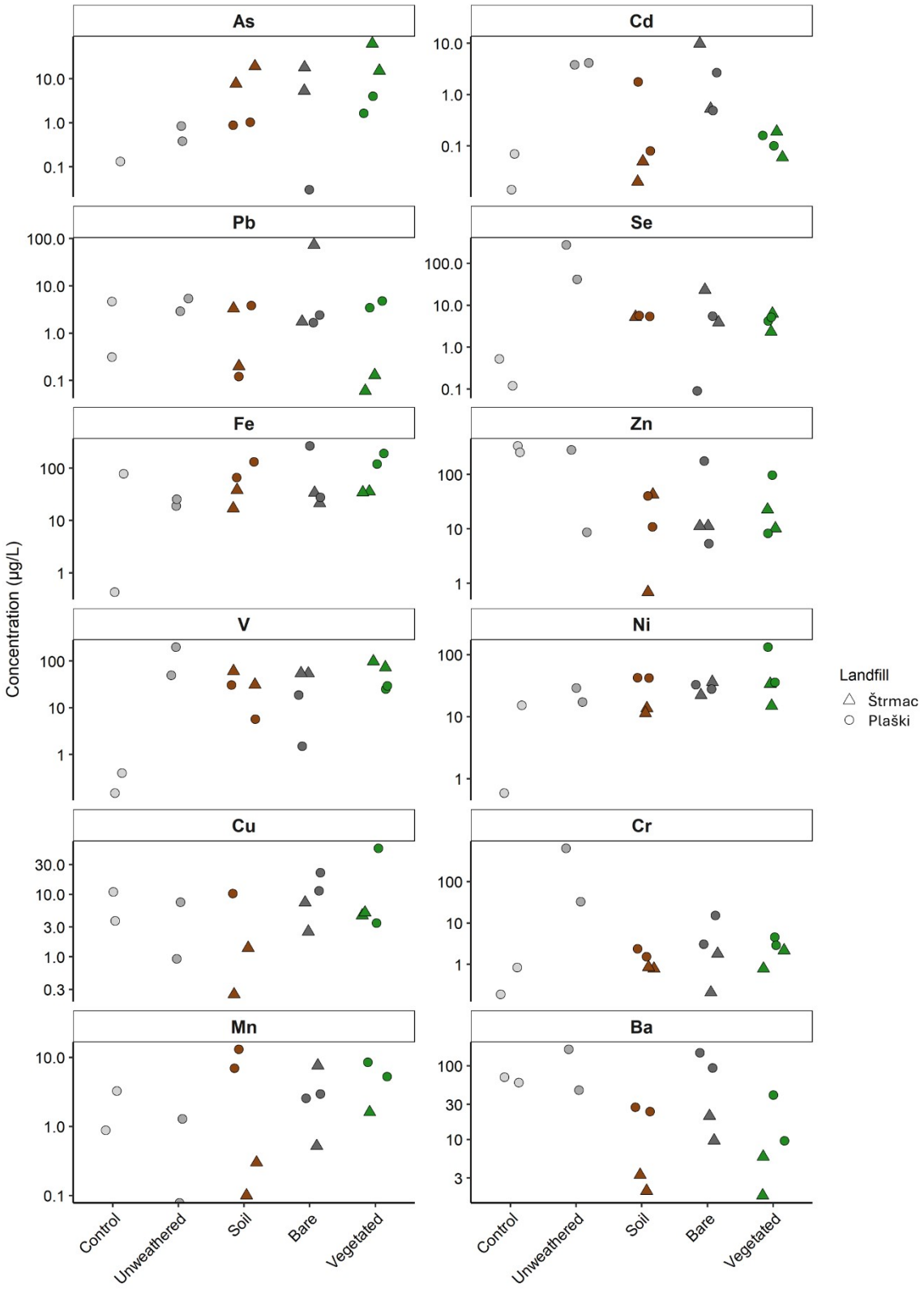


**Figure S1.** Concentration (log-scale) of selected elements in control, unweathered, soil, bare, and vegetated samples. Concentrations of all measured elements are in Supplementary material (Tab. S2 and 3).

**Table S8.** One-way ANOVA results for seed germination (SG), mitotic index (MI), and chromosomal aberrations (CA) in samples from the Štrmac and Plaški landfills. Degrees of freedom (df), F values, and p values are shown. Tukey's HSD test was applied when ANOVA indicated significant differences ($p < 0.05$).

| Endpoint | Site | Phase | Treatments included | df_between | df_within | F | p-value |
|---|---|---|---|---|---|---|---|
| SG | Štrmac | Exposure | Cneg, LŠ1, LŠ4, LŠ5, LŠ7, LŠ8, LŠ11 | 6 | 21 | 6.38 | 0.001 |
| | Plaški | Exposure | Cneg, LP1, LP3, LP5, LP8, LP9, LP10 | 6 | 21 | 17.4 | <0.001 |
| MI | Štrmac | Exposure | Cneg, LŠ1, LŠ7, LŠ5, LŠ4, LŠ8, LŠ11, FA, BA, Cpos | 9 | 40 | 8.42 | <0.001 |
| | Plaški | Exposure | Cneg, LP8, LP9, LP5, LP1, LP3, LP10, Cpos | 7 | 32 | 10.8 | <0.001 |
| | Štrmac | Recovery | Same as exposure (Štrmac) | 9 | 40 | 1.60 | 0.147 |
| | Plaški | Recovery | Same as exposure (Plaški) | 7 | 32 | 1.69 | 0.147 |
| CA | Štrmac | Exposure | Cneg, LŠ1, LŠ7, LŠ5, LŠ4, LŠ8, LŠ11, FA, BA, Cpos | 9 | 40 | 6.74 | <0.001 |
| | Plaški | Exposure | Cneg, LP8, LP9, LP5, LP1, LP3, LP10, Cpos | 7 | 32 | 4.41 | 0.002 |
| | Štrmac | Recovery | Same as exposure (Štrmac) | 9 | 40 | 3.01 | 0.008 |
| | Plaški | Recovery | Same as exposure (Plaški) | 7 | 32 | 1.27 | 0.299 |

**Table S9.** Percentage of observed disturbed phases and most common disturbances in Štrmac samples

| | Total cells | Dividing cells | P | M | A | T | MI | Std. Err. | No. of Aberr. | CA | Std. Err. | Micronucl. | Polycentric phase | Lagging/ Vagrant | Ana bridge | Spindle disturbance | Not centred phase | Stickiness | Doubled phase | Ring/rope Chrom. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Štrmac - Treatment | | | | | | | | | | | | | | | | | | | | |
| **Cneg** | 6817 | 407 | 235 | 75 | 34 | 63 | 6.03 | 0.57 | 3 | 0.73 | 0.48 | | 1 | | 1 | | | | | 1 |
| **LŠ1** | 6204 | 280 | 136 | 62 | 36 | 46 | 4.53 | 0.51 | 2 | 0.78 | 0.48 | | | 1 | | | 1 | | | |
| **LŠ7** | 5651 | 148 | 67 | 40 | 22 | 19 | 2.67 | 0.19 | 36 | 24.2 | 2.27 | | 1 | 10 | 2 | 12 | 1 | 6 | | 4 |
| **LŠ8** | 5136 | 168 | 92 | 37 | 21 | 18 | 3.15 | 0.87 | 11 | 4.32 | 2.82 | | | 3 | 2 | 1 | 1 | 2 | | 2 |
| **LŠ11** | 7063 | 208 | 103 | 50 | 32 | 23 | 3.06 | 0.55 | 30 | 14.6 | 4.47 | 1 | 2 | 8 | 2 | 9 | 2 | 5 | | 1 |
| **LŠ5** | 5291 | 136 | 60 | 33 | 26 | 17 | 2.58 | 0.53 | 27 | 19.6 | 2.95 | 3 | 3 | 3 | | 6 | | 9 | | 3 |
| **LŠ4** | 6403 | 224 | 131 | 55 | 18 | 20 | 3.65 | 0.53 | 26 | 11.6 | 1.37 | | 2 | 5 | | 10 | 1 | 5 | | 3 |
| **Cpos** | 5527 | 20 | 10 | 8 | 0 | 2 | 0.35 | 0.16 | 1 | 5.56 | 5.56 | | | | | 1 | | | | |
| Štrmac – Recovery | | | | | | | | | | | | | | | | | | | | |
| **Cneg** | 6707 | 359 | 215 | 78 | 40 | 26 | 5.36 | 0.17 | 10 | 3.10 | 0.44 | 1 | 3 | 4 | 1 | 1 | | | | |
| **LŠ1** | 7894 | 265 | 158 | 50 | 27 | 30 | 3.71 | 0.85 | 14 | 3.59 | 3.05 | | | 4 | | 4 | 1 | 2 | 1 | 2 |
| **LŠ7** | 6852 | 222 | 142 | 45 | 17 | 18 | 3.27 | 0.75 | 21 | 8.66 | 3.27 | | 1 | 3 | 1 | 9 | 3 | | 2 | 2 |
| **LŠ8** | 6977 | 348 | 179 | 86 | 36 | 47 | 5.10 | 0.35 | 26 | 7.82 | 2.62 | | 3 | 7 | 5 | 6 | 3 | | 1 | 1 |
| **LŠ11** | 6187 | 242 | 135 | 55 | 24 | 28 | 3.52 | 0.89 | 9 | 2.90 | 1.13 | | 1 | 1 | | | | 5 | | 2 |
| **LŠ5** | 5971 | 221 | 121 | 52 | 25 | 23 | 3.73 | 1.00 | 15 | 4.58 | 2.13 | | 1 | 4 | 1 | 5 | 1 | | 1 | 2 |
| **LŠ4** | 8807 | 289 | 179 | 51 | 29 | 30 | 3.31 | 0.66 | 28 | 9.12 | 1.25 | 3 | 1 | 7 | 3 | 7 | 2 | 3 | 1 | 1 |
| **Cpos** | 6101 | 185 | 95 | 42 | 31 | 17 | 2.97 | 0.86 | 23 | 12.0 | 3.13 | | 3 | 5 | 4 | 4 | 3 | 3 | 1 | |

**Table S10.** Percentage of observed disturbed phases and most common disturbances in Plaški samples

| | Total cells | Dividing cells | P | M | A | T | MI | Std. Err. | No. of Aberr. | CA | Std. Err. | Micronucl. | Polycentric phase | Lagging/ Vagrant | Ana bridge | Spindle disturbance | Not centred phase | Stickiness | Doubled phase | Ring/rope Chrom. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plaški - Treatment | | | | | | | | | | | | | | | | | | | | |
| **Cneg** | 5642 | 186 | 75 | 62 | 24 | 25 | 3.29 | 0.21 | 5 | 2.97 | 1.22 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 2 |
| **LP8** | 6279 | 225 | 106 | 59 | 36 | 24 | 3.59 | 0.21 | 55 | 24.7 | 4.37 | 0 | 3 | 19 | 2 | 14 | 1 | 7 | 0 | 7 |
| **LP9** | 6566 | 201 | 109 | 54 | 24 | 14 | 3.64 | 0.79 | 46 | 18.1 | 5.05 | 0 | 1 | 11 | 0 | 19 | 0 | 10 | 0 | 7 |
| **LP1** | 6003 | 111 | 42 | 37 | 14 | 18 | 1.94 | 0.66 | 14 | 13.2 | 4.07 | 0 | 0 | 2 | 0 | 8 | 0 | 4 | 0 | 0 |
| **LP5** | 6265 | 216 | 107 | 45 | 43 | 21 | 3.39 | 0.39 | 48 | 22.9 | 1.87 | 0 | 4 | 22 | 4 | 13 | 3 | 2 | 1 | 0 |
| **LP10** | 5678 | 214 | 108 | 50 | 32 | 24 | 3.93 | 0.48 | 30 | 14.4 | 2.08 | 0 | 1 | 10 | 1 | 10 | 0 | 1 | 0 | 7 |
| **LP3** | 5942 | 214 | 121 | 52 | 25 | 16 | 3.66 | 0.44 | 26 | 14.5 | 7.11 | 0 | 2 | 8 | 1 | 10 | 0 | 4 | 0 | 0 |
| **FA** | 4521 | 107 | 51 | 23 | 26 | 7 | 2.37 | 0.32 | 35 | 32.6 | 5.47 | 0 | 4 | 11 | 5 | 10 | 0 | 3 | 0 | 2 |
| **BA** | 5665 | 156 | 61 | 36 | 31 | 28 | 2.56 | 0.50 | 39 | 20.6 | 5.26 | 0 | 7 | 18 | 2 | 9 | 1 | 2 | 0 | 0 |
| **Cpos** | 5958 | 41 | 19 | 13 | 2 | 7 | 0.69 | 0.35 | 3 | 6.00 | 4.76 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| Plaški – Recovery | | | | | | | | | | | | | | | | | | | | |
| **Cneg** | 6256 | 288 | 112 | 92 | 38 | 36 | 4.51 | 0.08 | 11 | 6.17 | 1.94 | 0 | 0 | 5 | 2 | 0 | 3 | 1 | 0 | 0 |
| **LP8** | 6382 | 160 | 90 | 36 | 20 | 14 | 2.47 | 0.77 | 14 | 8.19 | 6.96 | 0 | 2 | 3 | 2 | 3 | 0 | 1 | 1 | 2 |
| **LP9** | 5279 | 221 | 104 | 55 | 25 | 37 | 4.16 | 1.02 | 40 | 13.9 | 3.38 | 0 | 3 | 9 | 3 | 15 | 0 | 4 | 1 | 5 |
| **LP1** | 6282 | 222 | 105 | 61 | 23 | 33 | 3.63 | 0.87 | 19 | 14.3 | 3.28 | 0 | 4 | 6 | 2 | 4 | 0 | 0 | 1 | 0 |
| **LP5** | 5367 | 228 | 113 | 52 | 31 | 32 | 4.24 | 1.38 | 47 | 15.5 | 6.43 | 0 | 7 | 12 | 3 | 18 | 2 | 2 | 2 | 1 |
| **LP10** | 5797 | 247 | 141 | 45 | 24 | 37 | 4.20 | 0.39 | 29 | 11.3 | 3.20 | 0 | 0 | 10 | 1 | 13 | 0 | 2 | 2 | 1 |
| **LP3** | 5884 | 316 | 170 | 67 | 39 | 40 | 5.44 | 0.38 | 58 | 13.5 | 4.15 | 0 | 6 | 18 | 2 | 23 | 0 | 0 | 0 | 9 |
| **FA** | 6781 | 287 | 127 | 86 | 41 | 33 | 4.24 | 0.49 | 57 | 20.9 | 4.99 | 0 | 5 | 18 | 0 | 27 | 0 | 1 | 2 | 3 |
| **BA** | 5328 | 272 | 120 | 75 | 34 | 43 | 5.14 | 0.32 | 40 | 14.5 | 3.61 | 0 | 0 | 3 | 6 | 6 | 0 | 1 | 0 | 2 |
| **Cpos** | 5286 | 159 | 81 | 46 | 17 | 15 | 2.98 | 0.83 | 11 | 4.01 | 2.43 | 0 | 3 | 3 | 0 | 4 | 0 | 1 | 0 | 0 |