

Summary

The main aim of the presented work was a comprehensive assessment of selected plant species (*Plantago lanceola*, *Plantago major*, *Taraxacum officinale*) and soil in terms of their usefulness in bioindication studies, including the ecological risk assessment for urban areas. Selected plant species and soil material were collected in June 2017 in five Polish cities (Gliwice, Częstochowa, Lubliniec, Piekary Śląskie and Ruda Śląska) and Ostrava (Czech Republic). In each of the examined cities, five sites have been selected: four of them were related to the presence of environmental pollution source (steel mills, mines, routes), and one site was considered as potentially pollution-free, being a recreational area (park). All examined cities, with the exception of Lubliniec, in the last century, were industrial centers, mainly of the mining and metallurgical industry. Lubliniec was selected for the research as the reference city due to the forest areas located within the city limits and the lack of industrial pollution emitters. The analysis of ecophysiological and biochemical parameters of the study plant species (ascorbic acid content, proline, RWC, leaf pH, guaiacol peroxidase activity, APTI, Cd, Zn, Pb, Mn and Fe content) and soil material (enzymatic activity, pH, organic matter content and tested heavy metals) were carried out in urban ecosystems under various anthropogenic pressure. The ecological risk assessment was estimated by using the enrichment factor (EF), the contamination factor (CF), the pollution load index (PLI) and the potential ecological risk index (PER). The analysis of the soil material showed a clear relationship between the enzymatic activity and analyzed metals content (Mn, Fe, Zn, Pb and Cd), the pH value and also the organic matter content. Based on the conducted research, it was found that selected species - *Taraxacum officinale*, *Plantago major* and *Plantago lanceolata* demonstrated different ecophysiological reactions in response to environmental stress and, therefore, can be recommended for bioindication studies. Among the three tested species, the plantain (*Plantago major*) was the most sensitive to air pollution, in its leaves was recorded the

lowest average content of proline ($1.3 \mu\text{mol g}^{-1}$ fw) ascorbic acid (11.69 mg g^{-1} fw), the lowest pH (5.63) and the lowest mean APTI value (14.07). On the other hand, the most resistant species to air pollution was the dandelion (*Taraxacum officinale*), which showed the highest average values of the examined ecophysiological parameters and the highest APTI value (16.04) in comparison to other study species. A several-fold difference in the metal concentrations (Zn, Cd, Pb, Fe and Mn) between washed and unwashed plant material indicates a disturbing state of air pollution and the dust fall containing the analysed metals on the leaf surface of study species. The highest average content of metals in the washed plant material in the case of Cd and Mn (4.55 mg kg^{-1} and $112.87 \text{ mg kg}^{-1}$ respectively) was observed in the *Taraxacum officinale* leaves, the highest content of Fe and Pb was recorded for *Plantago lanceolata* ($368.09 \text{ mg kg}^{-1}$ and 21.75 mg kg^{-1} respectively), and for Zn it was in *Plantago major* leaves ($130.14 \text{ mg kg}^{-1}$). The highest average concentration of metals for unwashed plant material in case of Fe and Zn ($2324.5 \text{ mg kg}^{-1}$ and $253.78 \text{ mg kg}^{-1}$ respectively) was found in *Plantago major* leaves, for Cd and Mn was observed in the *Taraxacum officinale* leaves (6.12 mg kg^{-1} and $351.77 \text{ mg kg}^{-1}$ respectively) and for Pb was found in *Plantago lanceolata* leaves ($313.65 \text{ mg kg}^{-1}$). Particular attention in the study was paid to the cities of Piekary Śląskie and Ruda Śląska, where the acceptable toxicity levels in soil and in plant material were exceeded. The ecological risk calculation allowed us to define the above-mentioned cities as areas with high and very high ecological risk. The health risk index (HRI) analysis showed different values depending on the element and study site. There was no health risk related to the potential consumption of the studied species in terms of the toxic effects of Fe and Zn; however, it is not recommended to consume (e.g. as herbs) the tested species at sites with $\text{HRI} > 1$, especially in Piekary Śląskie and Ruda Śląska.