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Original Research

Use of Turfgrasses in Landfill Leachate Treatment

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Abstract

Landfills are the most popular means of waste disposal in Poland. Unfortunately, most of them leak and pollute surface waters with harmful underground leachate. Although there are many methods of purification of landfill leachate, they are generally complex and expensive. One simpler and less expensive method involves the use of turfgrasses and the accumulation of toxic elements from landfill leachate in their biomass. They are also used for their soil-forming, anti-erosive, and decorative properties. In an experiment at the municipal waste landfill in Wrocław Swojczyce, we determined the accumulation of heavy metals from leachate by five species of sown grass cultivars. The best cultivars with regard to heavy metal accumulation were the *Festuca ovina* cultivar Noni and *Lolium perenne* cultivar Inka.

Keywords: municipal waste landfill, heavy metal accumulation, landfill leachate, turfgrasses

Introduction

In Poland, despite the introduction of increasingly innovative waste treatment methods (e.g. composting, incineration), waste disposal relies mainly on deposition at municipal landfills [1], with an adverse affect on the environment, including air, soil, and vegetation [2]. The landfills pose the greatest threat to the quality of surface, ground, and tapwater, and reserves of public water supply [3-5].

Polish landfills are mostly located at disused sand, gravel, and clay workings, and in uncultivated agricultural areas, usually with permeable geology. In some cases, waste is deposited directly into workings filled with underground water or rain water [6]. Fortunately, an increasing number of new landfills in Poland are being equipped with modern multiple safety liners [7].

Permeable underlying geology results in the spread of environmentally hazardous leachate [1] produced by the percolation of rainwater through the waste and the flow of surface waters and groundwater, which elute organic compounds and minerals, the products of biological, physical and chemical transformations within waste [8]. Landfill leachate varies in colour, from beige-green to dark brown and black, smelling of hydrogen sulfide and stale water [7].

The composition of landfill leachate is diverse and depends on the type of waste, the volume of infiltrating water, the age of the landfill, waste storage technologies, and the susceptibility of waste to degradation [2, 9]. Leachate usually has a higher concentration of organic and inorganic compounds than municipal wastewater [1], and is also potentially dangerous due to the presence of pathogenic microorganisms [1, 8].

The volume of landfill leachate depends on many factors, such as weather conditions (precipitation, evaporation, insolation), hydrology (surface and groundwater inflows), waste disposal technique (the degree of waste compaction, waste moisture, retention, the protection of the landfill's top layer), and landfill age.

An environmentally friendly and relatively cheap method of leachate treatment [10], in comparison to many traditional methods, is phytoremediation, especially phytoextraction [11]. This technique involves the extraction of pollutants from soil through their accumulation in the aboveground and underground plant parts which are then

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subject to periodic collection and destruction [12]. Very high phytoremediation potential, especially with regard to the accumulation of heavy metals, can be observed in grasses [13, 14].

Grasses are widely used in the stabilization of landfill space in biological reclamation [15-17]. They have developed different mechanisms of detoxification and deactivation of anthropogenic pollutants that they absorb from soil [18].

Grasses are highly resistant to the presence of large amounts of harmful compounds in contaminated liquids, including landfill leachate. The accumulation and neutralization of toxins occur on the physiological pathway [19] and constitute an environmentally friendly method of landfill leachate treatment [20]. When the contaminated biomass is burned for energy, further pollution is avoided through the purification of waste gases by appropriate filters [11].

This paper examines the efficiency of different turfgrass species and cultivars with respect to the accumulation of heavy metals from landfill leachate.

Material and Methods

The experiment was performed in the eastern part of the city of Wrocław, on the northwestern slope of Swojczyce landfill (Fig. 1).

Swojczyce municipal landfill was established in 1973 on permeable geology, without any protection against the contamination of groundwater by leachate from the deposited waste. In 1992 the landfill underwent technical and biological reclamation, and was subsequently closed [21]. This experiment was performed at the closed and recultivated landfill in 2007.

The experiment was established on anthropogenic soil without a developed profile, formed by deposition of mineral waste on the landfill slope. On the basis of the percentage content of mechanical fractions in the bulk sample, the examined soil was classified as light dusty loam (according to the classification of the Polish Institute of Soil Science and Plant Cultivation – IUNG).

Fig. 1. Location of the experiment and leachate at the Swojczyce municipal landfill.

This experiment used a split-block method with two variable factors. Factor I (A) was the dose of leachate used for watering the turfgrass: A_0 – control (no leachate), A_1 – use of leachate from the landfill, 17 m^3/ha/month, A_2 – leachate from the landfill, 36 m^3/ha/month. Factor II (B) was a grass species: B_1 – *Festuca arundinacea* cultivar Asterix, B_2 – *Lolium perenne* Inka, B_3 – *Festuca rubra* Nimb, B_4 – *Poa pratensis* Nandu, and B_5 – *Festuca ovina* Noni. After necessary preparation of the ground at the landfill, the aforementioned grass species were seeded, while the leachate was used once a month throughout the entire growing season.

After three years of watering the turfgrasses with two different doses of the leachate (17 and 34 m^3/ha/month), soil and vegetation at the turfgrasses were subjected to laboratory analysis. The chemical analysis of leachate from the Swojczyce landfill was performed once a year. The composition of leachate from the landfill was compared with maximum pollution rates for wastewater introduced to water and ground (according to the Decree of the Minister of Environment of 24 July 2006, Journal of Laws 31 July 2006 [22, 23]). Permissible levels were exceeded for the aerobic parameters (BOD_5, $ChZT_{Cr}$), nitrite nitrogen, ammonium nitrogen, nitrate nitrogen, chlorides, sulfates, potassium, and sodium. The leachate had alkaline pH, high salinity and the natural content of heavy metals. The high salinity of the leachate resulted in our using relatively low doses of leachate per month of the growing season (17 m^3 and 34 m^3) in order to avoid the destruction of turf.

The grasses were subjected to evaluation of their bonitation index (according to the Polish National Research Centre for Cultivar Testing – COBORU), including the "general aspect" (A_o), a visual assessment on a 9-grade scale, where 9 is the best value and 1 is the worst. The results of the evaluation were transformed using the Poisson formula $\sqrt{x} + 0.5$ for > 1 to > 10 [24] in order to obtain a continuous distribution, a prerequisite for the analysis of variance. Then an analysis of variance for split-blocks was performed, using a statistical program by prof. Rudnicki [25]. The statistical *F* was determined in order to verify significant differences, and then the LSD according to Tukey's multiple comparison test at the significance level α=0.05. The graph describing the general aspect presents the real numbers to maintain the nine-grade scale, while the LSD is presented as a value after the transformation.

After the chemical analysis of vegetation and soil, the heavy metal bioaccumulation factor was determined for the examined species of grasses, dividing the content of an element in soil by its content in the plant. Medians and upper and bottom quartiles were calculated, as shown in diagrams below in the Results section.

Results

The assessment of the general aspect showed the most attractive appearance in *Lolium perenne* cultivar Inka, and the worst in *Festuca ovina* Noni and *Poa pratensis* Nandu

(Fig. 2). The landfill leachate in both doses significantly increased the aesthetic value of the recultivation turfgrasses in the third year of the experiment (Fig. 3).

The performed chemical analysis the examined turfgrasses showed that among the examined heavy metals, only nickel levels increased and exceeded the background value (0.1-5.0 mg/kg). The concentrations of copper and zinc were natural (at 5-30 mg/kg and 25-150 mg/kg, respectively) and were not toxic. The natural and toxic levels for grasses were compared with values presented by [26].

The observed concentrations of heavy metals in the soil at the Swojczyce landfill were within permissible limits (according to the Decree of September 2002 on soil quality standards, Journal of Laws No. 165, Item 1359 [22]). Comparing these values with threshold values according to [26], the heavy metal concentration in the examined soil were at natural levels.

After the chemical analyses of the grasses and soil, the bioaccumulation factor was calculated for Cu, Zn, and Ni.

The highest Cu bioaccumulation factor was recorded for *Festuca rubra* Nimba, and the lowest for *Festuca arundinacea* Asterix (Fig. 4).

The highest Zn bioaccumulation factor was observed for *Festuca ovina* Noni, and the lowest for *Festuca rubra* Nimba (Fig. 5).

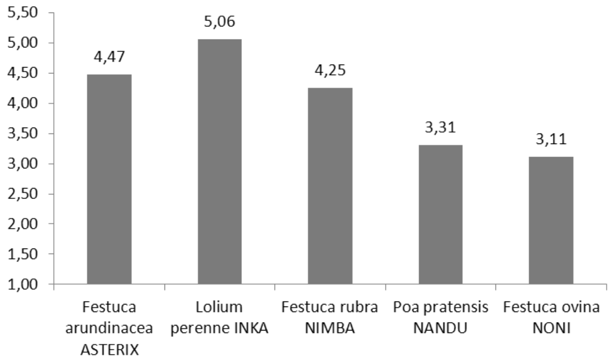

Fig. 2. General aspect (A_o) of the examined turfgrasses in 2007-09 (LSD=1.65).

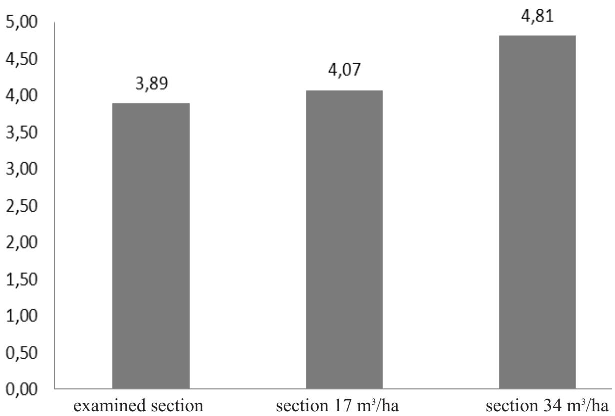

Fig. 3. Effect of landfill leachate on the general aspect (A_o) of the examined turfgrasses in 2009 (LSD=0.75).

Fig. 4. Copper bioaccumulation factor.

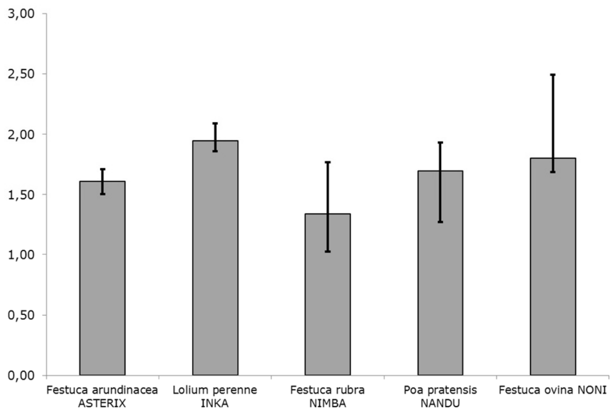

Fig. 5. Zinc bioaccumulation factor.

Fig. 6. Nickel bioaccumulation factor.

The highest Ni bioaccumulation factor was observed for *Festuca ovina* Noni, and the lowest for *Poa pratensis* Nandu and *Festuca arundinacea* Asterix (Fig. 6).

Discussion

The use value of the turf is best characterized by the general aspect (aesthetic value) [27]. In this paper, the best general aspect was observed for *Lolium perenne* Inka, and the worst for *Festuca ovina* Noni and *Poa pratensis* Nandu. These results are consistent with the findings of [28], who also observed the best aesthetic value for *Lolium perenne*, and the worst for *Festuca ovina*.

At the Swojczyce municipal landfill, the concentrations of heavy metals did not exceed permissible amounts for plants [29], except a slightly higher Ni concentration. Similarly, in soil the content of all heavy metals was within legally permissible limits (according to the Decree of 9 September 2002 on soil quality standards, Journal of Laws No. 165, Item 1359 [22]). Additionally, the comparison of heavy metal concentrations in soil at the Swojczyce landfill with limit values [29] shows that they did not deviate from natural levels. These findings are consistent with the report of [6, 33] at Maślice landfill, where the heavy metal concentrations in grasses and soil were also within natural levels.

Copper. In this study, the highest accumulation of this element was observed in the Nimba variety of *Festuca rubra* and *Lolium perenne* Inka. These results confirm report [30] who observed the highest Cu bioaccumulation in *Lolium perenne* Inka. [31] found that the best uptake of copper was in the *Festuca ovina* Noni.

Zinc. The best accumulation of this element was found in *Festuca ovina* Noni and *Lolium perenne* Inka. Studies by [31] and [32] confirm these results, showing high levels of this element in *Lolium perenne*.

Nickel. In this study nickel was best accumulated by the *Festuca ovina* Noni and *Lolium perenne* Inka.

In the determination of individual elements in a plant, one should take into account the degree and direction of movement of these elements in a plant, which is diverse and depends both on biological factors and the specific qualities of elements. Ni and Zn are moderately mobile when it comes to the transport to the aboveground parts, and Pb, Cu, and Cd are poorly mobile and concentrate in roots [29].

Conclusions

1. The best general aspect of turfgrass watered with landfill leachate was observed for *Lolium perenne* Inka, and the least attractive turf was observed for *Festuca ovina* Noni and *Poa pratensis* Nandu.
2. Heavy metal concentrations in vegetation and soil at the Swojczyce landfill were not toxic and were within natural limits.
3. Among the examined grasses, the best species for heavy metal accumulation were *Festuca ovina* Noni and *Lolium perenne* Inka.

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