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Original Research

Research into the Occurrence of Some Plant Species as Indicators of Landfill Impact on the Environment

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Abstract

Our paper focuses on complex research into the issue of waste disposal and the possibilities of using bioindicators to assess landfill impact on the surroundings. In 2010 we conducted a floristic survey and set up a list of the occurring species of vascular plants. The subject of research was surface area of the landfill and its immediate surroundings. During floristic research in 2010 we recorded 88 species that were compared with the list of 94 plants detected in 2007. Based on vegetation biomonitoring, we did not find any adverse influence of the landfill on the biotic composition of the environment. Neither had we recorded any alarming signs such as, e.g., leaf area chlorosis or necrosis, which would indicate direct impact on the local environs due to the operation of the sanitary landfill.

Keywords: bioindicators, vegetation biomonitoring, landfill, landfill impact, waste

Introduction

Work (Research) Objective

Our research deals with the issue of land filling and with the possible use of biological indicators to assess the impact of landfill on its surroundings. The problem is topical as land filling remains the most widespread technology for the disposal of communal waste in the Czech Republic. The main reason is seen in economic aspects of other waste disposal technologies, insufficient infrastructure, the capacity of other technical waste handling facilities, and favorable natural conditions for the construction of landfills. Another reason is a certain distrust of citizens in other technologies used in waste recovery and waste disposal facilities (e.g. communal waste incineration plants, bio-gas stations for the utilization of biologically degradable waste, etc.).

A general statement can be made that land filling has always had a negative impact on the landscape and on the environment. Potential adverse effects of the landfill on the environment and unfavourable influence on plants are in detail characterized in the publication "Evaluation of waste landfill impact on the environment with the use of bioindicators" [1].

Flora Monitoring

Monitoring by bioindication is focused primarily on the cumulative impact of individual factors of anthropogenic origin, evaluating the response of living organisms on the condition of the environment and its changes. The biological methods employed in environmental analysis may be, as Gadzała-Kopciuch et al. suggested [2], divided into two groups: bioanalytics (the use of biological matter for envi-

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ronmental analyses; biosensors, biotests), biomonitoring (the use of biota in classical chemical analysis – early warning system; bioindicators) [2]. The response of living organisms may differ under the combined effect of individual harmful substances; some combinations can increase or even decrease the individual effects. This is why the response of an organism often differs from the measured values of chemical and physical analyses, which may be critical and exceed admissible values but not elicit any reaction, and on the other hand a dramatic negative reaction may be induced by the combined action of more factors at tolerable levels.

The main objective of monitoring by bioindication is to utilize the capacity of some plants and animals to respond more readily to changes in their environment compared with humans. Plants and animals often respond to the increasing environmental load in a much more sensitive way than humans do. Monitoring by bioindication allows us to record changes occurring within a relatively long period of five and more years. Trends of development can be predicted by means of data analysis.

Botanical and Geobotanical Site Monitoring

Plant organisms play an important role in their natural habitats – they supply oxygen, control organic substance circulation and biological balance of the soil and bottom deposits, and provide food and shelter to other organisms. Phytoindicators are more and more frequently used for ecosystem quality assessment due to their sensitivity to chemical changes in environmental composition and the fact that they accumulate pollutants. The use of plants as bioindicators has many advantages, including low costs, the possibility of long-term sampling, and high availability. Their disadvantage is the necessity to take into account the physical conditions, impact of environment properties (growth rate disturbed by large amounts of pollutants, soil type and fertility, humidity), and genotype diversity in a given population [2].

Monitoring of plants and their communities represents a research method that is based on the following two fundamental aspects:

- natural vegetation reacts sensitively to changes in species composition to changes of soil chemism caused, for example, by a suddenly increased content of some elements and organic compounds, contamination with heavy metals, organic contaminants, etc. Monitoring uses indicator plant species and evaluates changes in the species composition of communities and the ecological valence of plant species occurring on monitored plots
- certain types of contamination show up in a specific disturbance of plants (symptomatological assessment of the impact of factors on living plants – e.g. necroses, chloroses, nanisms, color of leaf tissues, excessive biomass increment, etc.).

Results from the field inventory of the species composition and health condition of flora and plant communities make it possible to judge the status of the location in respect of the acute or chronic occurrence of contamination and impact of human activities.

The method allows us to:

- determine sources and the character of impacts and of possible contamination
- ascertain the character of acting substances
- establish directions and dissemination patterns of acting substances (surface runoff, sub-surface seepage)
- assess the impact upon environmental constituents (soil, water, air)

In studying vegetation, primary attention is paid to the species composition of the vegetation cover on the monitored site and to possible representative species protected pursuant to Act No. 114/1992 Coll. on nature conservation and landscape protection as amended.

Material and Methods

Characteristics of Natural Conditions in the Territory

The area belongs in the Kojetín bioregion [5] situated in central Moravia and occupying the geomorphological subunit of Středomoravská niva (Central Moravia Floodplain) within the complex of Hornomoravský úval Graben. The bioregion is formed by a broad alluvial plain with regulated rivers. Biota is of azonal character and dominated by agrocoenoses, preserved floodplain forests, remainders of meadows and ponds with abundant fauna.

According to Quitt [6], the entire region lies in warm zone T2. Weather is warm with abundant precipitation. Soils dominating in the bioregions are Gleyic Fluvisols; typical Fluvisols on sandy basements occur only on levees along the Bečva River, on a short section of the Morava River near Kojetín and on a low terrace at Chropyně. The soils have developed on non-carbonate sediments. In the space among Troubky, Chropyně, and Moštěnice there are isles of typical Chernozems. Gleyic Chernozems, Mollic Gleysols to Haplic Chernozems developed south of Kroměříž and Hulín along the edge of the floodplain. Greyzems and Luvisols occur on low terraces northwest of Přerov. Histosols occupy only small areas – fertile peat soils and negligible is the occurrence of poor brunic arenosols on elevations.

Vegetation

The bioregion lies in the thermophytic and occupies the central part of phytogeographic subdistrict 21b – Hornomoravský úval Graben. Potential vegetation is formed by alluvial forests of the *Ulmenion* suballiance, which pass into oak-hornbeam woods (*Carpinion* alliance). Natural substitute vegetation in place of the floodplain forests was represented by inundated meadows of the alliance *Alopecurion pratensis* and vegetation of the *Cnidion venosi* alliance was reaching into the area from the south. Typical vegetation around water surfaces is that of *Phragmition communis* and *Caricion gracilis* alliances. Flora is rather uniform, with the occurrence of some marginal elements. The location is also reached by some species washed from higher elevations such as chervil *Anthriscus nitida* or red campion (*Melandrium sylvestre*). Some of them, namely *Dentaria glandulosa*, squill *Scilla praecox*, and *Hacquetia epipactis,* show evident affiliation to the Carpathians. From the south, the area is also reached by skullcap *Scutellaria hastifolia*, spurge *Tithymalus palustris,* and bittercress *Cardamine matthiolii*.

Current Condition of the Landscape

Colonization of river alluvium edges is prehistoric. Species composition of local forests is largely natural; in some places, the forests were converted into lignicultures of mainly poplar. Fishponds were built at bioregion margins. Large flooded sandpits still occur today on the confluence of the Morava and Bečva rivers. Deforested areas used to be largely meadows, a greater part of which was converted into fields or their species composition was affected by the intensification of agricultural production.

The area is built of Paleogene rocks (layers of calcareous clays, marls, and sandstones). Soils of brown-earth type occurring on a greater part of the area pass into gley soils in the southern section formed by the watercourse alluvium.

The ample shrub layer is formed of blackthorn, common privet, dogwood, single-seed hawthorn, spindle tree, and wild brier. The herb layer shows a considerable representation of thermophilous species such as *Orchis militaris*, lesser butterfly orchid (*Platanthera bifolia*), greater butterfly orchid (*Platanthera chlorantha*), common twayblade (*Listera ovata*), cowslip (*Primula veris*), yellowhead *Inula ensifolia*, *Verbascum chaixii* subsp. *austriaca*, clusterhead *Dianthus carthusianorum*, carline *Carlina acaulys*, spiny restharrow (*Ononis spinosa*), agrimony (*Agrimonia eupatoria*), monkswort (*Nonea pulla*), common milkwort (*Polygala vulgaris*), clustered bellflower (*Campanula glomerata*), crater lake blue (*Veronica teucrium*), broomrape (*Orobanche*) sp., sedge (*Carex tomentosa*), and others.

Basic Characteristic of the Kuchyňky Landfill

The Kuchyňky Landfill is situated in a triangular space delimited by main roads connecting the villages of Zdounky, Nětčice, and Troubky-Zdislavice at a distance of ca. 1,800 m NNW of the church in Zdounky, 750 m NNW of the built-up area limits in Zdounky, and 450 m SW of the boundary line of Nětčice. The landfill lies in the cadastral area of Nětčice, on parcels 256/1, 256/2, 256/3, 256/4, 256/5, 256/6, and 256/7. In terms of maintenance, the landfill is classified in the S-category (other waste, sub-category S-003). The designed area of the landfill is 70,700 m^2 in five stages with a total volume of 907,000 m^3, i.e. ca. 1,000,000 tons of waste. Up to now, Stage I of 19,200 m^2 has been constructed together with parts of Stage II (5,500 m^2) and Stage III (7,500 m^3). Planned service life of the facility is up to the year 2018. The facility receives waste (category of other waste) from a catchment area with a population of ca. 75,000 residents. The annually deposited amount of waste is ca. 40,000 ton, 50% of which is from the communal sphere. The approved landfill sector for waste of sub-category S-001 has not been opened yet. The sector will be intended for the disposal of waste (category of other waste) with the low content of organic biologically degradable substances. A sector of the landfill will be intended largely for the disposal of asbestos-containing wastes, gypsum-based waste, stabilized waste, waste with high sulphur content, and waste with increased metals content. Waste with the substantial content of organic biologically degradable substances must not be stored in that sector.

Methodology of Research on Selected Plant Species in Landfill Environs

A team of researchers conducted floristic research in landfill environs in 2010 and set up a list of vascular plant species occurring in the area. The subject of research was the surface area of the landfill itself and its nearest environs at a distance gradient, i.e. in two zones of landfill surroundings:

Zone 1 – Landfill space and a belt 50 m wide in direct contact with the landfill

Zone 2 – Belt of 100 m wide in contact with the landfill (control) (Fig. 1).

Characteristics of detected plants were borrowed from available literary sources [3]. The floristic research included photographic documentation of recorded vascular plant species.

Floristic composition was explored in individual segments demarcated by the above-mentioned zones. Species abundance was established by valuating the simple presence of the species: 1 yes, 0 no, N not identified – irrespective of population abundance. Species in the segments are listed in Table 1.

During the floristic research conducted in 2010 we detected 88 plant species, compared to 94 species listed by [7]. Our attention was focused exactly on these species as their presence or absence may indicate a change and hence the influence of the landfill on the immediate surroundings. Most important in assessing the impact of the landfill on the

Fig. 1. Zones of landfill and landfill surroundings.

Table 1. Plant species occurring in the location in relation to habitat character.

Plant species	Area of landfill zone 1 – 2007	Landscape greenery zone 2 – 2007	Area of landfill zone 1 – 2010	Landscape greenery zone 2 – 2010
Acer platanoides L.	1	1	1	1
Acer pseudoplatanus L.	0	1	0	1
Achillea millefolium L.	1	1	1	1
Aegopodium podagraria L.	1	1	1	1
Agrostis stolonifera L.	1	1	N	N
Allium angulosum L.	0	1	1	1
Allium sp.	0	1	N	N
Anthriscus sylvestris L.	1	1	1	1
Arctium lappa L.	1	1	1	1
Arctium tomentosum MilL.	0	1	N	N
Arrenatherum elatius L.	1	1	N	N
Artemisia vulgaris L.	1	1	1	1
Ballota nigra L.	0	1	1	1
Bellis perennis L.	N	N	1	1
Bromus erectus Huds.	1	1	1	1
Bromus inermis Leyss.	0	1	N	N
Calamagrostis epigeios L.	1	0	N	N
Capsella bursa-pastoris L.	1	0	1	0
Carduus nutans L.	1	0	1	0
Carex distans L.	0	1	N	N
Chaerophyllum aromaticum L.	0	1	0	1
Chelidonium majus L.	N	N	1	1
Cichorium intybus L.	1	1	1	1
Cirsium arvense L.	1	0	1	0
Convolvulus arvensis L.	1	1	1	1
Conyza canadensis L.	1	0	1	0
Cornus mas L.	1	1	1	1
Coronilla varia L.	1	1	N	N
Crataegus monogyna Jacq.	1	1	1	1
Crepis biennis L.	1	1	1	1
Dactylis glomerata L.	1	1	N	N
Daucus carota L.	1	1	1	1
Delphinium elatum L.	1	0	1	0
Equisetum arvense L.	N	N	1	1
Eragrostis minor Host	1	1	N	N
Euonymus europaeus L.	1	1	1	1
Euphorbia cyparissias L.	N	N	1	1
Euphorbia helioscopia L.	N	N	1	1
Festuca altissima All.	1	1	1	1
Festuca ovina L.	1	0	N	N
Festuca rubra L.	1	0	N	N
Fraxinus excelsior L.	0	1	0	1

Table 1. Continued.

Plant species	Area of landfill zone 1 – 2007	Landscape greenery zone 2 – 2007	Area of landfill zone 1 – 2010	Landscape greenery zone 2 – 2010
Galeipsis tetrahit L.	1	1	1	1
Galium aparine L.	1	1	1	1
Galium mollugo L.	1	1	1	1
Galium verum L.	0	1	0	1
Geranium pratense L.	1	0	1	0
Germanium pusillum L.	N	N	1	0
Heracleum sphodylium	1	1	N	N
Hypericum perforatum L.	1	1	1	1
Juglans regia L.	1	1	1	1
Knautia arvensis L.	1	1	1	1
Lamium album L.	1	1	1	1
Lamium purpureum L.	N	N	1	1
Lathyrus niger L.	N	N	0	1
Lathyrus tuberosus L.	1	0	1	0
Lepidium ruderale L.	1	0	1	0
Leucabthemum vulgare Lamk.	1	1	1	1
Ligustrum vulgare L.	1	1	N	N
Lolium perenne L.	1	1	1	1
Lotus corniculatus L.	1	0	N	N
Malva neglecta Wallr.	N	N	1	1
Matricaria recutita L.	N	N	1	1
Melandrium album MilL.	1	1	1	1
Pastinaca sativa L.	1	0	N	N
Picea abies L.	1	0	1	0
Picea pungens Engelm.	1	0	1	0
Picris hieracioides L.	1	0	1	0
Pilosella piloselloides L.	1	0	N	N
Plantago intermedia L.	1	1	N	N
Plantago lanceolata L.	1	1	1	1
Plantago major L.	1	0	1	1
Poa annua L.	1	0	1	0
Poa trivialis L.	1	1	1	1
Polygonum aviculare L.	1	1	N	N
Potentilla anserina L.	N	N	1	1
Potentilla reptans L.	N	N	1	0
Primula veris L.	N	N	0	1
Prunella vulgaris L.	1	0	1	0
Prunus spinosa L.	1	1	1	1
Quercus robur L.	0	1	0	1
Ranunculus acris L.	1	1	1	1
Ranunculus repens L.	1	0	1	0
Reseda luteola L.	1	0	N	N

Table 1. Continued.

Plant species	Area of landfill zone 1 – 2007	Landscape greenery zone 2 – 2007	Area of landfill zone 1 – 2010	Landscape greenery zone 2 – 2010
Rhamnus catharcica L.	1	0	N	N
Rorippa austriaca (Crantz) Besser	1	0	1	0
Rosa sect. Caninae L.	1	1	1	1
Rumex obtusifolius L.	1	1	1	1
Salvia pratensis L.	1	1	1	1
Salvia verticillata L.	1	0	1	0
Sambucus nigra L.	1	1	1	1
Scorzonera hispanica L.	1	0	1	0
Setaria viridis (L.) P. Beauv.	1	0	N	N
Sisymbrium loeselii L.	N	N	1	0
Stellaria media (L.) Vill.	N	N	1	1
Swida sanquinea (L.) Opiz	1	1	1	1
Symphytum officinale L.	1	1	1	1
Symphytum tuberosum L.	0	1	0	1
Tanacetum vulgare L.	1	0	1	0
Taraxacum sect. ruderalia Kirschner, H. Ollgaard et Štěpánek	1	1	1	1
Thlaspi arvense L.	N	N	1	0
Tilia cordata Mill.	1	1	N	N
Trifolium campestre Schreb.	N	N	0	1
Trifolium dubium Sibth.	1	0	1	1
Trifolium pratense L.	1	1	1	1
Trifolium repens L.	1	1	1	1
Tussilago farfara L.	1	0	N	N
Urtica dioica L.	1	1	1	1
Valeriana officinalis L.	1	0	1	0
Verbascum thapsus L.	1	1	1	1
Veronica chamaedrys L.	N	N	0	1
Viburnum lantana L.	1	0	1	0
Abundance	85	64	78	64
Specially protected species	1	2	1	2

Simple presence of the species: 1 yes, 0 no, N not identified.

nearest environs is the occurrence of less common, rare or protected species.

Results

Inventory of Individual Species and their Evaluation

The floristic composition was determined in the individual zones (Zone 1 and 2) and compared with the results of the final report from 2007. Plant species occurring in the area in 2007 and 2010 in relation to habitat character are listed in Table 1.

The results indicate that the floristic composition corresponds to stand types and land use – with no distinctive environmental impact of the landfill. The highest species abundance shows the landfill area in which the most significant mosaic structure in the location exists at present (with ruderal, segetal, meadow, and shrubby types of biotopes occurring next to the landfill body). Segments of agro-coenoses where species abundance is constituted primarily by weed species (cultivated crops) show the lowest species diversity, which corresponds with the land use – arable land.

The occurrence of particularly protected species was recorded in 2007 and 2010 only in the shrubby balks of

Table 2. Informative capability of the species with respect to the plant community.

Indicator plant species	Ecological characteristic	Symptomatology	Indicator	Occurrence
Agrostis tenuis L.	metalophyte	orange to red-colored leaf margins	increased or high content of heavy metals in soil	not detected
Chaerophyllum aromaticum Ch. Temulum L.	nitrophilous species		higher to high nitrogen content, occurs on ruderal sites and anthropogenically eutrophicated soils	edge of agrocoenosis
Peplis portula L.	halotolerant acidotolerant	occurrence indicates soil salinization	slightly saline soils, acidic soils, moist to wet substrate	not detected
Plantago major L.	nitrophyte, tolerant to intense trampling and soil contamination by organic substances, S-strategist	nitrogen – vigorous growth, large leaves heavy metals – red to brown leaf margins	eutrophicated soils	symptoms not detected
Rorripa austriaca (Crantz) Besser	R-strategist	occurrence indicates anthropogenic impact	occurs on landfills containing solid communal waste	detected in the immediate surrounding of the active landfill
Sambucus ebulus L.	nutrient-intensive		occurs on eutrophicated soils	not detected
Sambucus nigra L.	nitrophilous species, apophyte		dominant occurrence and pure stands indicate considerable anthropogenic load, incl. organic pollution	part of shrubby belt between the dung pit and the eastern edge of the landfill
Silene vulgaris (Moench) Garcke	metalophyte	red-colored leaf margins, tiny habit	increased or high content of heavy metals in soils	not detected
Symphytum officinale L.	nutrients, namely nitrogen	large and dark-green leaves	indicates higher content of soil nitrogen	occurs in the shrubby mantle of the agrocoenosis, under no influence of the landfill
Taraxacum sect. ruderalia	nitrophilous species	large fragile leaves in leaf rosette, tall stalks in flowers	high content of soil nitrogen	symptoms not detected
Taraxacum sect. Ruderali Kirschner, H. Ollgaard et Štěpánek	metalophyte	red-colored leaf margins, nanisms	increased or high content of heavy metals in soil	symptoms not detected
Torilis japonica (Houtt.) DC.	nitrophilous species, neutral to mildly acidic soils		indicates higher content of soil nitrogen	not detected
Urtica dioica L.	nitrophilous species	vigorous growth, ample biomass, large leaves	high content of soil nitrogen	detected in the stand in contact with arable land

Zone 1, where *Cornus mas* (threatened species) occurs in a shrubby stand margin near the road to the landfill, and *Allium angulosum* (severely threatened species, C2) grows in the shrubby undergrowth near the landfill fence. The species composition of stands is dominated by *Prunus spinosa* and *Crataegus* spp., *Cerasus avium*, Rosa spp., *Cornus mas*, *Ligustrum vulgare*, *Swida sanguinea*, *Berberis* vulgaris, *Viburnum lantana,* and more. Stands of this syntaxonomic affiliation tend to expand into more valuable steppe stands on plots with a sufficient amount of nutrients.

A number of herb species such as *Galium mollugo*, *Agrimonia eupatoria*, *Coronilla varia*, *Fragaria moschata,* or *Geranium robertianum* occur in the stands of secondary bushes.

Assessment of the Impact of Factors

Symptomatic traits of the impact of the environment on plants were determined by assessing the impact of factors and activities on plant individuals, populations, and communities depending on the occurrence of symptoms in individuals, on species composition, and on the occurrence of indicator plant species.

Biomonitoring can be defined as a process in which the “analytical instruments” used, i.e. plant and animal organisms or their fragments, provide continuous, real-time analytical information [4]. Bioindication is a research activity allowing us to obtain a picture of the ecological situation on the basis of its important elements (e.g. species, ecological form, population, associationor community). Bioindicators are biological indicators of environmental quality, characterizing environmental conditions. Their tolerance is usually limited, so their presence or absence and health state enable us to determine some physical and chemical components of the environment without complicated measurements and laboratory analyses. Bioindicators according to Gadzała-Kopciuch et al. [2] may be divided into those responding to environmental changes in a visible way (morphological and physiological changes), and those whose reactions are invisible, but cumulate different substances (pollutants) whose concentrations may be determined. According to another division, qualitative and quantitative bioindicators can be distinguished. The former indicate the fact that a given species occurs in a given ecosystem, the latter allows us to determine the (optimum) number/concentration of representatives of a given species in a given ecosystem) [2].

The occurrence of plant species was studied in zones and informative capability of the species was assessed with respect to the plant community (Table 2).

Conclusion

Assessing the impact of the landfill on its environs, we based our study on the selected bioindicators present in 2010 and on the study "Monitoring of landfill impact on fauna, flora, and soil."

During the period of vegetation biomonitoring, we did not detect any significant impact of the landfill on the biotic composition of the environment and no symptoms of leaf area chlorosis or necrosis that would have indicated the direct impact of sanitary landfill operation on the location. The landfill has a functional system of drains combined with the system of ground sealing and the system of seepage water drainage pits. It further has a sophisticated system to check fencing, fly-offs, and to collect lightweight waste. Bad odors were detected only in the immediate vicinity of the landfill at high air temperatures; at a distance of 50 m from the landfill, bad odors were not detected any more. It is possible to conclude that the landfill has a safe and sophisticated technology of waste disposal.

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