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# VERIFICATION OF THE OCCURRENCE OF SOME PLANT SPECIES AS INDICATORS OF LANDFILL IMPACT ON THE ENVIRONMENT

Magdalena Vaverková, Dana Adamcová, František Toman

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## Abstract

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An ecological study was conducted on landfill site in Kuchyňky, Czech Republic. Our paper focuses on verification of research into the issue of waste disposal and the possibilities of using bioindicators to assess landfill impact on the surroundings. The subject of research was surface area of the landfill and its immediate surroundings. Sampling was carried out in 2010–2012 and compared with simple floristic list prepared in 2007. Floristic composition was explored in individual segments. Species abundance was established by valuating the simple presence of the species: 1 yes, 0 no, N not identified – irrespective of population abundance. During the floristic research conducted in 2010, we detected 88 plant species, in 2011 – 105 and in 2012 – 105 plant species, which were compared with 94 species listed in 2007. Based on repeated research we did not find any considerable influence of the landfill on the biotic composition of the environment.

verification of research, bioindicators, landfill, landfill impact, waste

## 1 INTRODUCTION

Landfilling is still the main waste disposal method in Europe and recent EU (European Union) legislation prescribes strict rules for waste disposal in landfills (European Union, Directive, 2008/98/EC of the European Parliament and of the Council of 19 November 2008) (Paoli *et al.*, 2012).

The public acceptance of waste disposal sites is very low owing to concern for adverse affects on the environment and human health, and landfills are often causes of concern for the population living nearby. Besides potential health hazards, concern on the environmental impact of solid waste landfilling relies on vegetation damage, unpleasant odors, fires and explosions, landfill settlement, groundwater and air pollution and global warming (Paoli *et al.*, 2012).

Waste landfills issues and related impact on the surroundings are the most recent topics not only in Czech Republic, but also all over the world (Kotovicová, 2005). Landfilling has been used for many years as the most common method for the disposal of solid waste generated by different communities (Komilis *et al.*, 1999). Despite the intensive efforts that are directed to the recycling and recovery of solid wastes, landfills remain and will remain an integral part of most solid waste management plans. Solid waste disposed in a landfill usually is subjected to a series of complex biochemical and physical processes, which lead to the production of both liquid and gaseous emissions (Al-Jarrah and Abu-Qdais, 2006).

Human activities have always generated waste. This was not a major issue when the human population was relatively small and nomadic, but became a serious problem with urbanization and the growth of large conurbations. Poor management of waste led to contamination of water, soil and atmosphere and to a major impact on environment and public health (Giusti, 2009). The impact can be evaluated in various ways. Among them, there is possibility to use the living organisms as indicators of environment state, so called bioindicators, to evaluate the effect of human activities on organisms' health, functioning of ecosystems, structure and functioning of the whole region. Changes in ecosystems or reasons for these changes can be evaluated on the basis of alteration in the behavior, appearance or occurrence of some organism or their concentration. Bioindication and biomonitoring are the methods which enable to evaluate these changes being not visible at first glance (Honzík, 1997).

Gadzała-Kopciuch suggests (Gadzała-Kopciuch *et al.*, 2004) that phytoindicators are more and more frequently used for ecosystem quality assessment due to their sensitivity to chemical changes in environmental composition and the fact 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. Lower plant organisms (grasses, mosses, lichens, fungi and algae) are used most often in analyses of atmospheric depositions, soil quality and water purity. Responses of trees and shrubs to the presence of pollutants are also observed. The assimilatory organs of trees, especially coniferous ones (pine, fir, spruce), are characterized by the capacity to accumulate air pollutants, which makes them suitable for the determination of residues of pesticides, polychlorinated biphenyls (PCBs), pentachlorophenol (PCP), hexachlorobenzene (HCB), hexachlorocyclohexane iosmers, dioxins and furans. Numerous and visible changes, like needle loss, crown thinning, changed bark color, increased needle fragility, enable us to estimate the level of environmental pollution (Gadzała-Kopciuch *et al.*, 2004; Kotovicová *et al.*, 2011).

Mosses and lichens are applied as indicators of environmental pollution due to their capacity to accumulate and store heavy metals and other toxins. Typical examples of a biological indicator of air pollution are lichens. Their major advantage is response repeatability in various habitats. Regardless of the investigation site and differences in the species composition, destruction zones are easy to distinguish. Due to their specific anatomic, morphological and physiological characters, lichens are among the organisms that die first as a result of excessive air pollution (Gadzała-Kopciuch *et al.*, 2004; Kotovicová *et al.*, 2011).

Lichens offer a unique opportunity to investigate the biological effects of air pollution, providing reliable information on the quality and characteristics of the environment (Paoli *et al.*, 2012).

High concentrations of xenobiotics in plants allow us to employ simple measuring methods, and the popularity of the above plant species enables biomonitoring in different geographical regions, on a continental or even global scale. The specific sensitivity of some species of land plants, e.g. pine *(Pinus silvestris)* or spruce *(Picea abies)* to the presence of $SO_2$ in the atmosphere allows determining the degree, range and structure of environmental degradation (Gadzała-Kopciuch *et al.*, 2004; Kotovicová *et al.*, 2011).

### 1.1 Hypothetical landfill impact on environment – nature of the problem

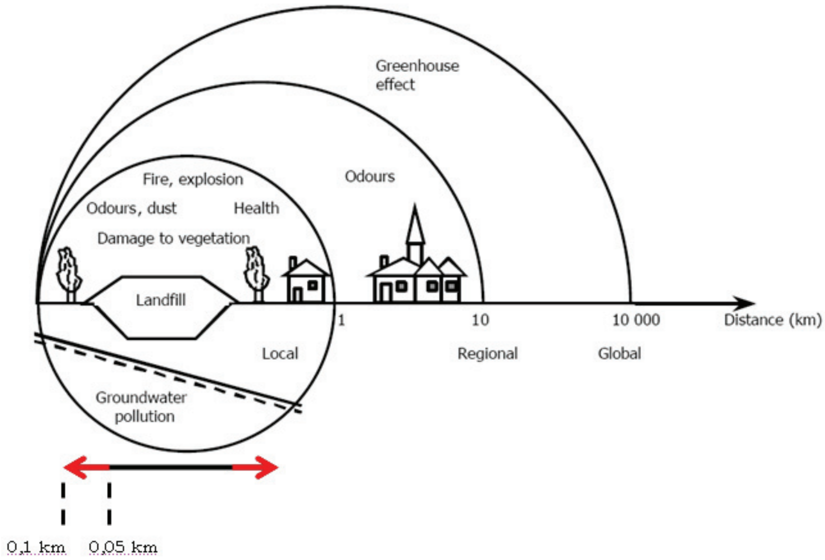
The main pollution issues associated with landfill sites are the production of potentially explosive gases and liquid leachate. Leachate emissions from landfill sites are of growing concern, primarily due to their toxic impact when released unchecked into the environment, and the potential for landfill sites to generate leachate for many hundreds of years following closure (Jones *et al.*, 2006).

Landfilled waste is comprised of a wide range of inorganic, natural and xenobiotic compounds, the mixture of which in turn affects the composition and polluting potential of the landfill (Kjedsen *et al.*, 2002). Municipal waste deposition is relatively least troublesome method of its utilization. However, this method is related to environmental risk issues (as illustrated by Fig.1), among which the most important are as follows: leachate from the landfill, formation of landfill gas, landfill stability, dust, carried small materials, odor, concentrated presence of rodents and birds, noise due to landfill operation.

### 1.2 Formation of landfill gas

After being disposed in landfills, solid waste undergoes complex physicochemical and biological reactions. As a result, organic substances are degraded into leachable liquids or landfill gases. Under anaerobic conditions, the degradation of organic substances generates a large amount of landfill gases comprised of methane and carbon dioxide, along with numerous trace gases, such as $H_2S$, $N_2O$ and CO. $CH_4$, $CO_2$ and $N_2O$ are anthropogenic greenhouse gases that may significantly contribute to global warming (Xiaoli *et al.*, 2011).

Gas emitted from landfill often contains compounds, which concentration considerably exceeds the concentration of the surrounding environment. Such concentrations may lead to the development of ecosystem with specific organisms. New conditions can be favorable for tolerant species, which can manage the emissions and use them in their metabolic process, or on the contrary can lead to the elimination of sensitive species (Gendebien *et al.*, 1992). The main components of landfill gas are methane (from 40% to 60%), carbon dioxide (from 35% to 50%), nitrogen (from 0% to 20%), oxygen (from 0% to 1%) and hydrogen sulphide (from 50 to 200 ppm) (Bove and Lunghi, 2006). Landfill gas can also contain trace compounds such as aliphatic and aromatic hydrocarbons, halogenated compounds and silicon-containing compounds up to a total concentration of 2000 $mg/m^3$ (Schweigkofler and Niessner, 1999). Hypothetically, plants (plant communities) in the ecosystem can be assumed to induce emissions and occurrence of polluted areas




1: *The different scales of the impacts of gas from landfills (after Kjeldsen, 1996, modified by Vaverková, Adamcová in 2013)*

under the influence of landfill gas. The pollution may be indicated by:

- the development of specific species content and/or external reactions of organisms,
- accumulation of contamination in plants.

The most common reason for disturbing vegetation in the vicinity of landfills is the presence of landfill gas in the root zone. The main reason for some damages is the deficiency of oxygen required to maintain root respiration. The emissions of landfill gas can diminish oxygen level in soil to the amount required by the majority of plants, e.g. 5–10%. And the increased concentration of $CO_2$ is toxic even at sufficient oxygen level. The usual $CO_2$ concentration in soil equals to 2%, and typical plants growth is provided at 5%. The concentration exceeding 20% is regarded as the phytotoxic level (Gendebien *et al.*, 1992). Plants present in the vicinity of landfills, constantly affected by local conditions, can be very interesting due to their diversity. The specified type of plants can be competitive and can grow when other species occur quite rarely. As some species are tolerant towards specific environmental conditions, it can be hypothetically assumed that plants (plant communes) can be used to evaluate the pollution/landfill impact (Gendebien *et al.*, 1992).

An improved understanding of landfill gas tolerant vegetation and its effect on methane oxidation will be helpful in improving the management of landfill sites and attenuating the emission of greenhouse gases. Currently, there is limited data regarding the effects of vegetation on methane oxidation in the cover soil of landfills (Xiaoli *et al.*, 2010).

### 1.3 Dust, carried small materials

Regarding constant emissions (dust) from the landfill, this will probably have a negative impact on the above-ground plant parts, especially due to shading, mechanical clogging or covering of stomata what can result in slowing down the photosynthesis, overheating of leaves, adsorption changes and the reflection of heat radiation or mechanical damage of leaf surface. Thus, it can directly affect biomass.

Reliable and regular environmental monitoring should be included in any process of ecological impact assessment of waste management, evaluating the ecological impacts of specific activities in support of regulatory procedures and providing consistent data for environmental management (Paoli *et al.*, 2012). In this scenario, biomonitoring is considered a valuable tool for the implementation of environmental policy on pollution control.

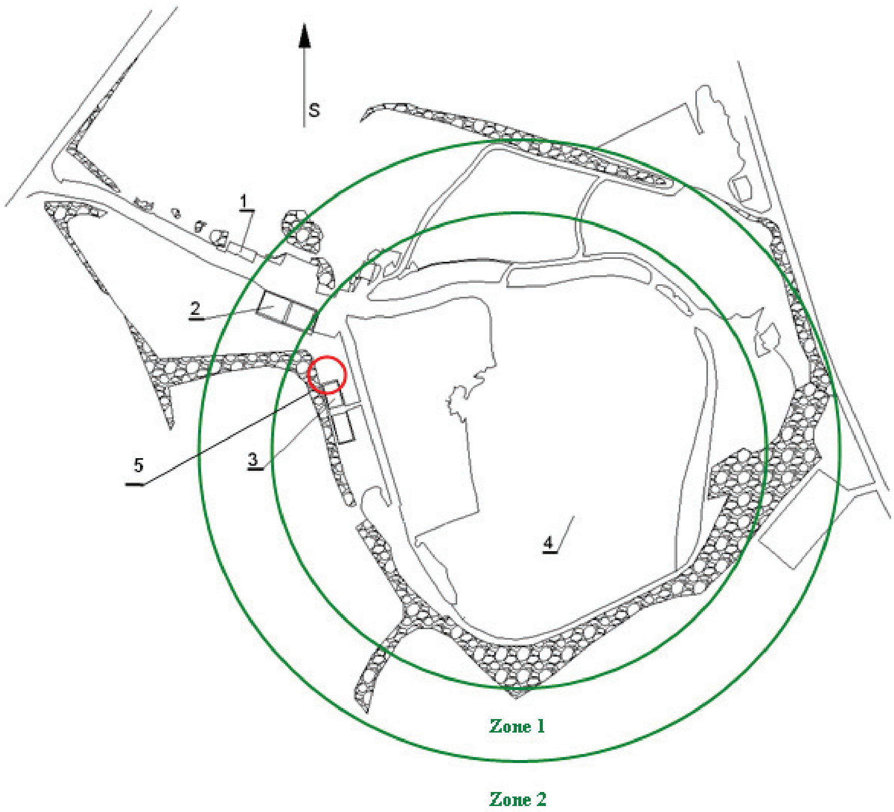
## 2 MATERIAL AND METHODS

### 2.1 Study site and methods

Examined landfill (characteristic of natural conditions in the territory, vegetation, current condition of the landscape, basic characteristic of the Kuchyňky landfill and methodology of data collection and research on selected plant species) were described in detail in "Research into the occurrence of some plant species as indicators of landfill impact on the environment" (Vaverková *et al.*, 2012) in Polish Journal of Environmental Studies and are not presented in this article.

### 2.2 Sample collection

The team of researchers conducted a simple floristic research in landfill environs in 2010, 2011, 2012 and set up a list of vascular plant species occurring in the locality (Vaverková *et al.*, 2012). 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:




2: *Zones of Kuchyňky landfill and landfill surrounding (Vaverková, Adamcová)*
1 – entrance gate, 2 – rainwater reservoir, 3 – drained water tank, 4 – landfill, 5 – habitat of Acer platanoides L.

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

Zone 2 – Belt of 100 m in width with a contact with the landfill (control) (Vaverková *et al.*, 2012) (Fig. 2).

Characteristics of detected plants were borrowed from available literary sources (Kubát *et al.*, 2002). 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 Tab. I.

During the floristic research conducted in 2010, we detected 88 plant species, in 2011 – 105 and in 2012 – 105 plant species, which were compared with 94 species listed by doc. ing. Barbara Stalmachová, CSc. in 2007 (Vaverková *et al.*, 2012; Stalmachová, 2007). 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 nearest environs appears the occurrence of less common, rare or protected species (Vaverková *et al.*, 2012).

## 3 RESULTS AND DISCUSSION OF RESULTS

### 3.1 Inventory of individual species and their evaluation

The floristic composition was determined in the individual zones in 2010–2012 and compared with the results of the final report from 2007 and 2010. Plant species occurring in the locality are listed in Tab. I. 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 locality exists at present (with ruderal, segetal, meadow and shrubby types of biotopes occurring next to the landfill body).

In contrast to the monitoring that was undertaken in 2007 and 2010 several new plant species occurred in the landfill area in 2011 and 2012 (see Tab. I). These species were probably dragged into the landfill together with waste: *Amaranthus hypochondriacus* L., *Calendula officinalis* L, *Datura stramonium* L., *Geranium pusillum* L., *Helianthus Tuberosus* L., *Humulus lupulus* L., *Linaria vulgarit*, *Medicago sativa* L., *Solanum nigrum* L. These ruderal plants are demanding of certain abiotic conditions (eg. nitrogen, light, disruption, humidity). Since landfill (secondary stands)

I: *Plant species occurring in the locality in relation to habitat character*

| Plant species | Zone 1 2007 | Zone 2 2007 | Zone 1 2010 | Zone 2 2010 | Zone 1 2011 | Zone 2 2011 | Zone 1 2012 | Zone 2 2012 |
|---|---|---|---|---|---|---|---|---|
| *Acer platanoides* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Acer pseudoplatanus* L. | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| *Achillea millefolium* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Aegopodium podagraria* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Agrostis stolonifera* L. | 1 | 1 | N | N | 1 | 1 | 1 | 1 |
| *Allium angulosum* L. | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| Allium sp. | 0 | 1 | N | N | N | N | N | N |
| *Amaranthus hypochondriacus* L. | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| *Anthriscus sylvestris* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Arctium lappa* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Arctium tomentosum* Mill. | 0 | 1 | N | N | 1 | 1 | 1 | 1 |
| Arrhenatherum elatius L. | 1 | 1 | N | N | 1 | 1 | 1 | 1 |
| *Artemisia vulgaris* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Ballota nigra* L. | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Bellis perennis* L. | N | N | 1 | 1 | N | N | N | N |
| *Bromus erectus* Huds. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Bromus inermis* Leyss. | 0 | 1 | N | N | N | N | N | N |
| *Calamagrostis epigeios* L. | 1 | 0 | N | N | N | N | N | N |
| *Calendula officinalis* L | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Callistephus chinensis | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Capsella bursa-pastoris* L. | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| *Carduus nutans* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Carex distans* L. | 0 | 1 | N | N | N | N | N | N |
| *Chaerophyllum aromaticum* L. | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| *Chelidonium majus* L. | N | N | 1 | 1 | 1 | 1 | 1 | 1 |
| *Cichorium intybus* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Cirsium arvense* L. | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| *Convolvulus arvensis* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Conyza canadensis* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Cornus mas* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Coronilla varia* L. | 1 | 1 | N | N | 1 | 1 | 1 | 1 |
| *Crataegus monogyna* Jacq. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Crepis biennis* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Dactylis glomerata* L. | 1 | 1 | N | N | 1 | 1 | 1 | 1 |
| *Datura stramonium* L. | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Daucus carota* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Delphinium elatum* L. | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| *Equisetum arvense* L. | N | N | 1 | 1 | 1 | 1 | 1 | 1 |
| *Eragrostis minor* Host | 1 | 1 | N | N | N | N | N | N |
| *Euonymus europaeus* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Euphorbia cyparissias* L. | N | N | 1 | 1 | 1 | 1 | 1 | 1 |
| *Euphorbia helioscopia* L. | N | N | 1 | 1 | 1 | 1 | 1 | 1 |
| *Festuca altissima* All. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Festuca ovina* L. | 1 | 0 | N | N | N | N | N | N |
| *Festuca rubra* L. | 1 | 0 | N | N | N | N | N | N |
| *Fraxinus excelsior* L. | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| *GaleOpsis tetrahit* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| Plant species | Zone 1 2007 | Zone 2 2007 | Zone 1 2010 | Zone 2 2010 | Zone 1 2011 | Zone 2 2011 | Zone 1 2012 | Zone 2 2012 |
|---|---|---|---|---|---|---|---|---|
| *Galium aparine* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Galium mollugo* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Galium verum* L. | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| *Geranium pratense* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Geranium pusillum* L. | N | N | 1 | 0 | 1 | 0 | 1 | 0 |
| *Helianthus Tuberosus* L. | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| Heracleum sphondylium | 1 | 1 | N | N | 1 | 1 | 1 | 1 |
| *Humulus lupulus* L. | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Hypericum perforatum* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Juglans regia* L. | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 |
| *Knautia arvensis* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Lamium album* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Lamium purpureum* L. | N | N | 1 | 1 | 1 | 1 | 1 | 1 |
| *Lathyrus niger* L. | N | N | 0 | 1 | 1 | 1 | 1 | 1 |
| *Lathyrus tuberosus* L. | 1 | 0 | 1 | 0 | N | N | N | N |
| *Lepidium ruderale* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Leucanthemum vulgare* Lamk. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Ligustrum vulgare* L. | 1 | 1 | N | N | 1 | 1 | 1 | 1 |
| Linaria vulgaris | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| *Lolium perenne* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Lotus corniculatus* L. | 1 | 0 | N | N | 1 | 1 | 1 | 1 |
| *Malva neglecta* Wallr. | N | N | 1 | 1 | 1 | 1 | 1 | 1 |
| *Matricaria recutita* L. | N | N | 1 | 1 | 1 | 1 | 1 | 1 |
| *Medicago sativa* L. | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| *Melandrium album* Mill. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Pastinaca sativa* L. | 1 | 0 | N | N | 1 | 0 | 1 | 0 |
| *Picea abies* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Picea pungens* Engelm. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Picris hieracioides* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Pilosella piloselloides* L. | 1 | 0 | N | N | 1 | 0 | 1 | 0 |
| *Plantago intermedia* L. | 1 | 1 | N | N | 1 | 1 | 1 | 1 |
| *Plantago lanceolata* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Plantago major* L. | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Poa annua* L. | 1 | 0 | 1 | 0 | 1 | 0 | N | N |
| *Poa trivialis* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Polygonum aviculare* L. | 1 | 1 | N | N | 1 | 1 | 1 | 1 |
| *Potentilla anserina* L. | N | N | 1 | 1 | 1 | 1 | 1 | 1 |
| *Potentilla reptans* L. | N | N | 1 | 0 | 1 | 0 | 1 | 0 |
| *Primula veris* L. | N | N | 0 | 1 | 0 | 1 | N | N |
| *Prunella vulgaris* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Prunus spinosa* L. | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| *Quercus robur* L. | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| *Ranunculus acris* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Ranunculus repens* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Reseda luteola* L. | 1 | 0 | N | N | 1 | 0 | 1 | 0 |
| *Rhamnus cathartica* L. | 1 | 0 | N | N | 1 | 1 | 1 | 1 |
| *Rorippa austriaca* (Crantz) Besser | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Rosa sect. Caninae* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| Plant species | Zone 1 2007 | Zone 2 2007 | Zone 1 2010 | Zone 2 2010 | Zone 1 2011 | Zone 2 2011 | Zone 1 2012 | Zone 2 2012 |
|---|---|---|---|---|---|---|---|---|
| *Rumex obtusifolius* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Salvia pratensis* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Salvia verticillata* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Sambucus nigra* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Scorzonera hispanica* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Setaria viridis* (L.) P. Beauv. | 1 | 0 | N | N | N | N | N | N |
| *Sisymbrium loeselii* L. | N | N | 1 | 0 | 1 | 0 | 1 | 0 |
| *Solanum nigrum* L. | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Stellaria media* (L.) Vill. | N | N | 1 | 1 | 1 | 1 | 1 | 1 |
| *Swida sanquinea* (L.) Opiz | 1 | 1 | 1 | 1 | 1 | 1 | N | N |
| *Symphytum officinale* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Symphytum tuberosum* L. | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| *Tanacetum vulgare* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| *Taraxacum sect. ruderalia* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Thlaspi arvense* L. | N | N | 1 | 0 | 1 | 0 | 1 | 0 |
| *Tilia cordata* Mill. | 1 | 1 | N | N | 1 | 1 | 1 | 1 |
| *Trifolium campestre* Schreb. | N | N | 0 | 1 | 0 | 1 | 0 | 1 |
| *Trifolium dubium* Sibth. | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Trifolium pratense* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Trifolium repens* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Tussilago farfara* L. | 1 | 0 | N | N | 1 | 0 | 1 | 0 |
| *Urtica dioica* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Valeriana officinalis* L. | 1 | 0 | 1 | 0 | 1 | 0 | N | N |
| *Verbascum thapsus* L. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Veronica chamaedrys* L. | N | N | 0 | 1 | 0 | 1 | 0 | 1 |
| *Viburnum lantana* L. | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| abundance | 85 | 64 | 78 | 64 | 94 | 78 | 95 | 76 |
| specially protected species | 1 | 2 | 1 | 2 | | | | |

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

provides such conditions, these species prosper in this area. Most of these species amply spread along rivers and streams, around roads and railway tracks as well as along the field edges, earthworks, rubble sites, landfills, nutrient-rich soils. That indicates that the landfill area is rich in nutrients and therefore suitable for eutrofic plant species.

Within the research that was undertaken in 2012 *Coprinus comatus* was identified in the landfill area. This fungus occurred at several stands all of which were located in the recultivated part of the landfill site. The fungus grows in groups on fertilized meadows, rubble sites, edges of broadleaved forests, often in ruderal stands. It belongs to cosmopolitan fungus and is spread all over the world. This fungus may be used as an indicator of significant content of nutrients. That is confirmed by its presence at the landfill site.

Further change in contrast to the research in 2007 and 2010 is the absence of *Juglans regia* L. in 2011 and 2012 at the landfill site. This species occurred in 2007 and 2010 both at the landfill site as well as in its nearest environs. Since this species prefers humid lowland areas with high contents of muck in soil and plenty of light, the area of landfill represented suitable conditions. Potential cause of its presence at the landfill was its dragging together with waste or self-seeding. In 2011 and 2012 its does not appear at the landfill site itself, only in its nearest environs. Potential cause of its absence is mechanical removal by landfill employees. *Prunus spinosa* L. was absent only in the research in 2012 both at the landfill site and its nearest surroundings. Most probably it was removed from the landfill area in the same manner as *Juglans regia* L.

Segments of agrocoenoses where the 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 2010–2012 only in the shrubby balks of Zone 1 where *Cornus mas* (rare plant species in the Czech Republic requiring further attention (C4a), protected by law within the category of threatened species) occurs in a shrubby stand margin near the road to the landfill, *Allium angulosum* (severely threatened species, in the Czech Republic protected by law in the same category (§ 2)) grows in the shrubby undergrowth near the landfill fence in 2007, 2010, 2011. In 2012 it was not identified. Its absence may signify amendment of biotope characteristics. The occurrence of this species shall be monitored in the following years.

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 other. 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 in each respective year.

The species *Acer platanoides* L. was identified in the landfill area in 2007, 2010–2012 next to the drained water tank (see Fig. 1). In 2012 was recorded at *Acer platanoides* L incidence of *Rhytisma acerinum* (Pers.) Fr. This species is characteristic of the occurrence of yellowish spots on which gradually develop black spots that grow and ultimately merge into one large black spot (so called tar spots). These spots are 7 to 10 mm large, with yellow lining. As a result of significant disruption, these leaves shed. *Rhytisma acerinum* (Pers.) Fr. belongs to Discomycetes taxonomic class. It does not comprise a wood destroying fungus, as this fungus attacks merely leaves, not wood. Currently it can only be found in the areas of the Czech Republic which are rather air-pollution-free. Due to ecosystem degradation this fungus is rapidly declining in the Czech Republic. The above described disease represents an air-clarity bioindicator.

Within the research in 2012 dust and small materials carried from the landfill site were recorded (predominantly polyethylene foils in various forms – packets, bags). These materials occurred on plants (trees and bushes) in the nearest surroundings of landfill.

## 4 CONCLUSION

A repeated ecological investigation was conducted on landfill and landfill surroundings. The results are summarized below.

The present work indicates that landfill sites are unique environment. Landfill vegetation offers high species diversity, accommodating not only common ruderal species but also vegetables and species listed as endangered. Since this diversity is partly due to the disposed wastes and the landfill operation, it does not necessarily indicate the emission of pollutants. During the period of vegetation biomonitoring in 2007 and 2010–2012, we did not detect any significant impact of the landfill. There was no evidence that landfill-related stresses propagated up and had population- or community-level consequences. The area where the landfill is located is appropriate in terms of its impact on the environment.

Landfill gas and landfill leachate may not necessary be limiting factors suppressing the bioactivity and growth of plants. The results provide evidence that landfill sites can be favourable habitat which supports a variety of plants.

These findings are relevant for waste management and for the evaluation of hazardous effects of landfills on biota. Moreover, to efficiently manage areas of ecological interest, we propose a continuous biomonitoring study to assess the effects of the Kuchyňky landfill on terrestrial ecosystems.


## SUMMARY

The team of researchers conducted a simple floristic research in Kuchyňky landfill environs in 2010, 2011, 2012 and set up a list of vascular plant species occurring in the locality. 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 of 50 m in width with a direct contact with the landfill

Zone 2 – Belt of 100 m in width with a contact with the landfill.

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. During the floristic research conducted in 2010, we detected 88 plant species, in 2011 – 105 and in 2012 – 105 plant species, which were compared with 94 species listed in 2007.

The present work indicates that landfill sites are unique environment. Landfill vegetation offers high species diversity, accommodating not only common ruderal species but also vegetables and species listed as endangered. Since this diversity is partly due to the disposed wastes and the landfill operation, it does not necessarily indicate the emission of pollutants. During the period of vegetation biomonitoring in 2007 and 2010–2012, we did not detect any significant impact of the landfill. There was no evidence that landfill-related stresses propagated up and had population- or community-level consequences. The area where the landfill is located is appropriate in terms of its impact on the environment.

Landfill gas and landfill leachate may not necessary be limiting factors suppressing the bioactivity and growth of plants. The results provide evidence that landfill sites can be favourable habitat which supports a variety of plants.

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Address

Mgr. Ing. Magdalena Vaverková, Ph.D., Bc. Ing. Dana Adamcová, Ph.D., prof. Ing. František Toman, CSc., Department of Applied and Landscape Ecology, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: magda.vaverkova@uake.cz, dana.adamcova@mendelu.cz, tomanf@mendelu.cz