INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

Nr 1/4/2012, POLSKA AKADEMIA NAUK, Oddział w Krakowie, s. 15–25
Komisja Technicznej Infrastruktury Wsi
Commission of Technical Rural Infrastructure, Polish Academy of Sciences, Cracow Branch

Magdalena Vaverková, Dana Adamcová

POTENTIAL IMPACT OF TWO LANDFILLS ON THE NEAR VICINITY WITH THE USE OF BIOINDICATORS

Summary

The research deals in complex with the issue of landfilling and with a possible use of biological indicators to assess the impact of landfill on its surroundings. The problem is topical as landfilling remains the most spread technology for the disposal of communal waste in the Czech Republic.

Assessing the impact of the landfill on its environs, we based our study on the selected bioindicators present in 1995 and in 2007 – 2010. During the period of vegetation biomonitoring, we did not detect any significant impact of the landfills 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 landfills operation on the locality. The Štěpánovice landfill and Kuchyňky landfill have 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. Both landfills are constructed and operated in compliance with the most modern and strictest requirements and standards.

Key words: bioindicators, biomonitoring, landfill, landfill impact, waste

INTRODUCTION

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 [Komils 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, 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 urbanisation 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 [Housti, 2009]. The impact can be evaluated in various ways. Among them, there is possibility to use 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 behaviour, 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].

RESEARCH OBJECTIVE

The research deals in complex with the issue of landfilling and with a possible use of biological indicators to assess the impact of landfill on its surroundings. The problem is topical as landfilling remains the most spread 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, capacity of other technical waste handling facilities and favourable 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 landfilling has always a negative impact on the landscape and on the environment [Vaverková et al., 2012].

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 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 exceeding admissible values but not eliciting any reaction and on the other hand, a dramatic negative reaction may be induced by the combined action of more factors at tolerable levels [Vaverková et al., 2012].

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 the man. Plants and animals often respond to increasing environmental load in a much more sensitive way than the humans does. Monitoring by bioindication allows 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 [Vaverková et al., 2012].

Botanical and geobotanical site monitoring

Plant 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 [Gadzała-Kopciuch et al., 2004].

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

– natural vegetation reacts sensitively by changes in the 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. The monitoring makes use of 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, colour 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 upon the status of the locality in respect of the acute or chronic occurrence of contamination and impact of human activities.

The method allows:

– to determine sources and the character of impacts and of possible contamination,

– to ascertain the character of acting substances,

– to establish directions and dissemination patters of acting substances (surface runoff, sub-surface seepage),

– to assess the impact upon environment constituents (soil, water, air).

In studying the vegetation, main attention is paid to the species composition of the vegetation cover on the monitored site and to possible representative species protected pursuant to the Act no. 114/1992 Coll. on nature conservation and landscape protection as amended [Kotovicová et al., 2011].

MATERIAL AND METHODS

Basic characteristic of the Štěpánovice and Kuchyňky landfills

The landfill of Štěpánovice is located 1 km north of Štěpánovice commune and 1 km south of Dehtín commune. GPS coordinates of the test point - 49°26'15.934"N, 13°16'55.352"E. The landfill has been operating since summer 1996. It is situated in the north part of widely opened valley directed towards W-E. The bottom part of this area is restricted with a nameless stream being the right tributary of Úhlava river. The upper part of the area is covered with woodland vegetation predominated by *Pinus sylvestris*. The south slope is used for agriculture. The landfill is located at the north slope from the valley axis. In the past, the landfill area was used as the meadow [Král, 2005].

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. 1800 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 year 2018. The facility receives waste (category of other waste) from a catchment area with the population of ca. 75 000 residents. The annually deposited amount of waste is ca. 40 000 tons of which 50% are from the communal sphere.

Sample collection at the Štěpánovice landfill

After selecting the place and obtaining the permit for landfill construction, the present manager conducted simple floristic tests in 1995 (he prepared a list of plant and lichens species which were then present in the tested area).

According to prepared list, 57 vascular plants and lichens were identified in the place of constructed landfill and the nearest vicinity and described. In 2007-2009, simple floristic tests were conducted in the vicinity of the landfill and the present list of vascular plants and lichens was elaborated. The studies covered the near vicinity of the landfill from its fencing to 60 metres from the fence. The profile of selected plants is from available literature data [Randuška et al., 1986; Kubát et al., 2002]. Species abundance was established by valuating the simple presence of the species: 1 yes, 0 no, N not identified – irrespective of population abundance. Vegetation was identified at the time of the survey. The studies conducted in 2007 and 2008 allowed to identify 56 vascular plants and 2 lichens, and in 2009 57 vascular plants which are compatible with the list of plants prepared by the landfill manager in 1995 [Král, 2006]. The vascular plants and lichens from the submitted list were thoroughly monitored as their presence or their possible shortage could indicate the change in environmental conditions, e.g., landfill impact on the near vicinity. Vascular plants less common, rare or protected seem to have the most significant meaning during the evaluation of landfill impact on the near vicinity.

Sample collection at the Kuchyňky landfill

The team of researchers conducted the floristic research in landfill environs in 2010 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 (control). Characteristics of detected plants were borrowed from available literary sources [Kubát et al., 2002]. 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, which were compared with 94 species listed by Stalmachová in 2007 [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.

RESULTS

Selected species of plants present in the vicinity of the Štěpánovice landfill

During the performance of field studies in years 2007-2009, 57 vascular plants and 2 lichens were identified in the landfill vicinity. The plants were tested using botanical-gravimetric analysis. *Cladonia arbuscula*, *Juniperus communis*, *Epipactis helleborine*, *Populus tremula* and *Polygala chamaebuxus* were selected as bioindicators of the landfill effect on the near vicinity. All mentioned vascular plants and lichens were identified in consecutive years 2007, 2008 and 2009, except for *Polygala chamaebuxus*. *Polygala chamaebuxus* appeared in 2009. This plant was commonly present in the area of constructed landfill and in its near vicinity (particularly on the north side towards the landfill, in the wood) [Král, 2006]. The construction of landfill probably caused the changes in biotope and destruction of this plant growing sites. Its reappearance in 2009 can demonstrate that environmental conditions in the vicinity of the landfill have been stabilised. As the soil seed bank contained undamaged diaspores (seeds) of *Polygala chamaebuxus*, it reappeared in its initial place. Repeated observations of the occurrence of *Cladonia arbuscula*, which is very sensitive to environmental pollution, can indicate good quality of the environment in the close vicinity of the landfill. The presence of *Juniperus communis*, which is the protected species in Czech Republic, demonstrates that the construction and exploitation of the landfill has not significantly altered natural conditions required by this plant. *Populus tremula* belongs to species which during short time colonise places with affected soil structure. This plant is sometimes called as the master of survival in difficult conditions. It is an ideally pioneer plant, extremely tolerable regarding habitat requirements, resistant to frost, drought, pests and environmental pollutants. Its presence may indicate some changes, e.g. soil damages, deteriorated environmental conditions which occurred during landfill construction. It grows in the occupied area for a long time even though the environmental conditions are subject to significant changes. The reoccurrence of *Polygala chamaebuxus*, and the presence of species originally growing in this area, namely *Cladonia arbuscula*, *Juniperus communis*, *Epipactis helleborine* may indicate that the landfill does not have a significant impact on the close vicinity.

Selected species of plants present in the vicinity of the Kuchyňky landfill

The floristic composition was determined in the individual zones (Zone 1 and 2) and compared with the results of the final report from 2007. 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). The 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 only in the shrubby balks of 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 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.

DISCUSSION

The strategy of using organisms growing on pollutants to indicate the presence of emission spot is a promising approach for the study of pollutants with varying emission flows. The method can be cost efficient because it overcomes the problems related to sudden variations in emissions.

Plants, naturally growing on contaminated soils, are usually tolerant to the conditions and do not show external signs of harm. However sampling organisms that are exposed to contaminant emissions is of practical interest as the strategy can provide information about exposure over a longer period of time e.g., landfill gas or polluted soils.

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].

Landfill potential impact on environment

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 [Kjeldsen et al., 2002]. Municipal waste deposition is relatively least troublesome method of its utilisation. However, this method is related to environmental risk issues, among which the most important are as follows: leachate from the landfill, formation of landfill gas, landfill stability, dust, carried small materials, odour, concentrated presence of rodents and birds, noise due to landfill operation. The potential impact of landfill on the near vicinity, particularly on plants, was evaluated on the basis of analysis of available materials. Just two impacts from the above mentioned ones were analysed. These were the formation of landfill gas and dust and carried small materials as they can have the significant impact on plants [Vaverková et al., 2012].

Formation of landfill gas

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 favourable 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 Neissner, 1999]. Hypothetically, plants (plant communities) in the ecosystem can be assumed to induce emissions and occurrence of polluted areas 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.

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. On the basis of conducted tests, it was found that waste management at Štěpánovice and Kuchyňky landfill complies with valid provisions of law. Landfills location and optimization of transport route significantly minimize the effect of landfill exploitation and used technique on natural environment. Landfills location and adjusted configuration of the area in the vicinity of waste landfill do not have a negative impact on inhabitants from a nearby village: Štěpánovice (Štěpánovice landfill), Zdounky, Netčice and Troubky-Zdislavice (Kuchyňky landfill). The influence of noise and dust on environment and daily life of inhabitants from the nearby area is minimal, without any importance. Obedience to technological process at the landfills prevents small materials carriage (they are regularly covered with the layer of neutral material and compacted with the use of a compactor). The protection of surface and ground water against leachate from the landfills is provided by the means of a special system of bottom isolation (geomembranes made from high density polyethylene HDPE) and drainage. The landfills are monitored and inspected on a regular basis. In addition to a daily inspection of the landfills, there is also an independent inspection of negative effects on the environment (at least twice a year), especially the monitoring of ground water and leachate from the landfills as well as the analysis of landfill gas formation.

Due to the above and considering relatively little traffic of vehicles through the landfill area, its exploitation (operation) is not a significant negative factor which influences the environment. The performed studies did not confirm the negative impact of landfill on the nearby area. This landfill is constructed and operated in compliance with the most modern and strictest requirements and standards.

CONCLUSION

Assessing the impact of the landfill on its environs, we based our study on the selected bioindicators present in 1995 and in 2007 – 2010. During the period of vegetation biomonitoring, we did not detect any significant impact of the landfills 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 landfills operation on the locality. Landfill vegetation in the near vicinity of the Štěpánovice and Kuchyňky landfill offers a high species diversity, accommodating not only common ruderal species but also 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. The present work indicates that landfill vicinity can be unique environment and that landfills may not necessary be limiting factors suppressing the bioactivity and growth of plants.

The Štěpánovice landfill and Kuchyňky landfill have 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. Both landfills are constructed and operated in compliance with the most modern and strictest requirements and standards. Bad odors were detected only in the immediate vicinity of the Kuchyňky landfill at high air temperatures; at a distance of 50 m from the landfill, bad odors were not detected any more.

Due to the above it is possible to conclude that the Štěpánovice landfill and Kuchyňky landfill have a safe and sophisticated technology of waste disposal with insignificant impact on the near vicinity. Biomonitoring pollution through bioindicators is crucial for the assessment of environmental quality and to improve our understanding of the response capacity of natural populations to pollution. It could be recommended to continue the initiated studies for better understanding the potential and ecological effect of appropriate use of vegetation in the landfill vicinity.

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Mgr ing. Magdalena Vaverková,
Ph.D., Bc.Ing.. Dana Adamcová, Ph.D
Mendel University in Brno,
Department of Applied and Landscape Ecology,
Zemědělska 1, 613 00 Brno