PROTECTION OF DRINKING WATER SOURCES AGAINST LANDFILL LEACHATES IN MORAVA RIVER BASIN, CZECH REPUBLIC

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ABSTRACT

The Morava Project is one of three pilot projects aimed at problems of water protection in the territory of the Czech Republic. Since 1992, the project has dealt with water protection in the Morava River basin, which represents about one third of the Czech Republic. Our research concerned protection of territories assigned to drinking water draw-off, used at the present time or in the future, and monitored potential sources of their pollution. One of the sources are landfills, especially old loads. Information on them is summarized in a database of the Ministry of the Environment "Environmental Loading Registration System". Closed landfills located near catchment areas were selected for a detailed study. The concentrations of pollutants in the leachates were mostly only slightly elevated (chromium, nickel, lead, cadmium, mercury, and non-polar hydrocarbons). From nutrients, elevated concentrations of NH_4^+ were found in some leachates. Ecotoxicity was tested by a battery of tests (*Thamnocephalus platyurus*, *Brachionus calyciflorus*, *Raphidocelis subcapitata*, and *Sinapis alba*). Most leachates were slightly toxic or toxic. The leachates can at favourable hydro-geological conditions endanger the drinking water sources, which supports the necessity of their supervision and monitoring.

Keywords: ground water, drinking water source, landfill leachate, water pollution, ecotoxicity

INTRODUCTION

The Morava Project is one of three pilot projects (together with the Labe and Odra Projects) aimed at problems of water protection in the territory of the Czech Republic and financed by the Governmental Board for Research and Development. Its goal is not only the creation of a professional base for fulfillment of strategic aims of state policy in the area of water protection according to river basins, but also the support of international activities. The main contribution of this project is the essential enlargement of knowledge on water quality, pollution sources, state of aqueous ecosystems, and necessary remedial measures in the whole Morava River basin (26,000 km^2); which represents about one third of the Czech Republic. The project respects the rules of the 2000/60/EC Council Directive which determines the framework of the European Community activities in the area of water policy.

The Morava Project has been solved by the T. G. Masaryk Water Research Institute (Brno branch) since 1992. It has dealt with the following groups of problems of water protection in the Morava River basin:

- point pollution sources
- diffuse pollution sources and landfills
- development of water quality and state of aqueous ecosystems
- state and development of the protection of ground water sources in use.

Problems of landfills in the Morava Project were always connected with the protection of water; particularly ground water sources. It was necessary to describe all landfills in the basin area by a unified methodology; and to specify those directly endangering drinking water sources. That is why a set of tables arose in 1992, summarizing the landfills according to their location in the districts of the Morava River basin, accompanied by a set of maps in a scale of 1:200,000. (It was continuously updated and used also for determination of urgency order of remediation measures according to water sources protection.) The schedule of closing and re-cultivation of the landfills was spread to the interval of 3 to 7 years. Risks of the landfills to the environment of the Morava River basin are demonstrated in Fig. 1.
The set of landfills monitored in the Morava river basin included 48 municipal and industrial landfills. They were chosen due to the type and quantity of the waste deposited, technical safety, and the possibility of hazardous leachates seeping into ground waters.

Most recently, we have been working with a database of the Ministry of the Environment of the Czech Republic. It was created by a team of specialists evaluating all landfills of the Czech Republic. At the present time, we use information on closed landfills from this Environmental Loading Registration System (ERS). The ERS includes not only landfills in the sense of the Waste Act, but also dumps, sludge-drying beds, landfills of secondary raw materials, illegal dumping and similar accumulations of various substances of anthropogenic origin that can cause environmental load. An overview of available knowledge on existing ecological loads can be obtained from the database (for example, see Tab. 2 summarizing the most important information on endangered drinking water sources). The data necessary for the solution of the above mentioned problems are given in part "Landfills":

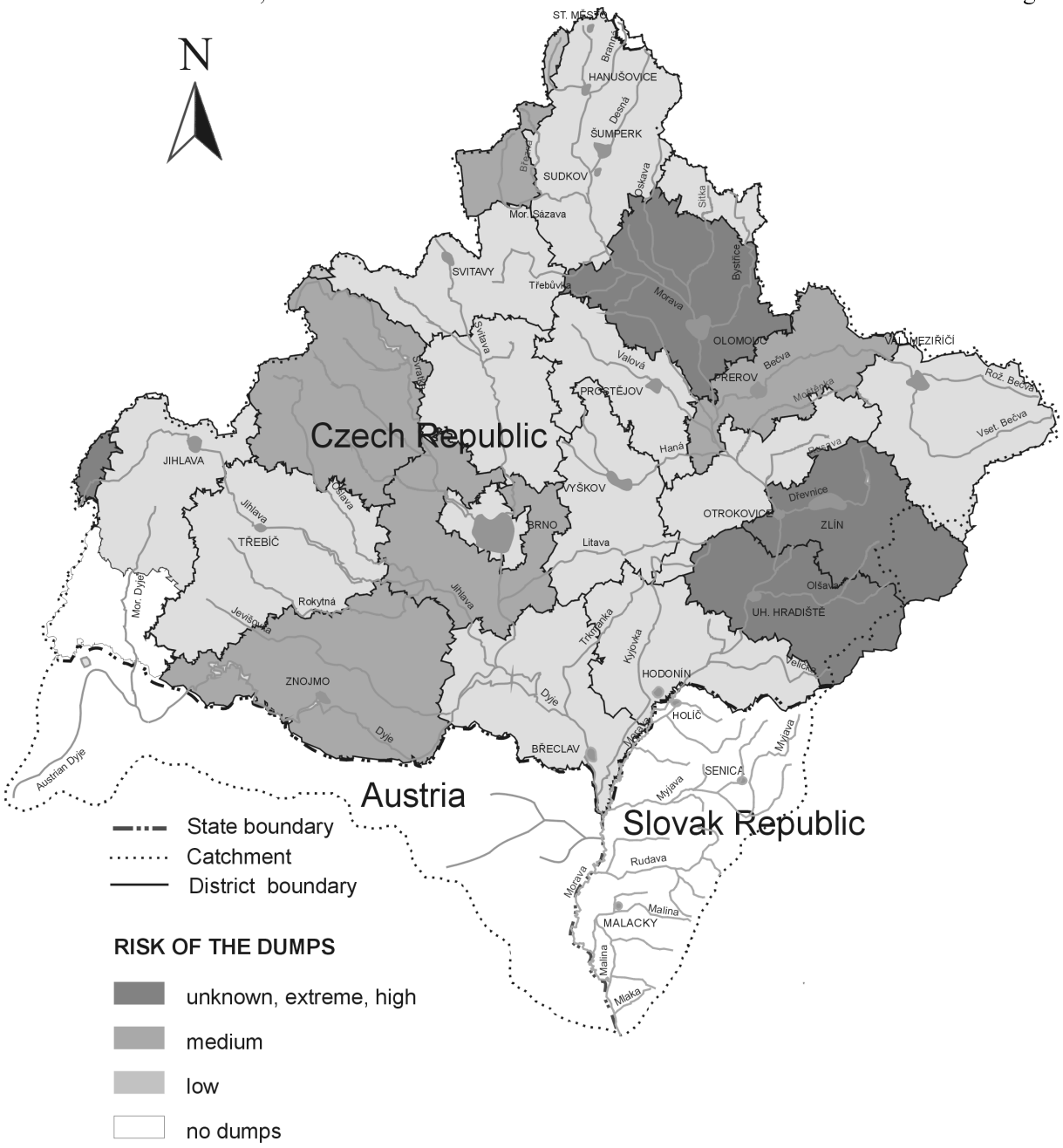

Fig. 1 The most frequent risk of the landfills in districts of the Morava river basin

1. Description of the landfill body and a brief characteristic of its function and operation (permission, etc.)
   The description of the landfill body includes the item "Landfill type" with the following options:
   A – closed, i.e. landfills closed before validity of the original Waste Act 238/91 Coll.;
   B – closed, i.e. landfills operated in 1991-1996 under special conditions due to the Waste Act 238/91 Coll. and closed since 31st July 1996;
   C – closed, i.e. landfills not granted by special conditions due to the Waste Act 238/91 Coll. and closed mostly in 1992-1993;
   D – open/controlled, i.e. legal landfills;
   E – open/not controlled, i.e. sites actively used for illegal waste deposition, where wastes were or have been deposited in a way endangering the environment;
   F – unknown, i.e. the type can be specified later after field investigation.

2. Description of deposited waste
3. Description of technical safety, equipment, and protection against negative effect on the environment
4. Risks due to: (i) location, (ii) type of deposited waste, (iii) potential effect on aqueous environment and soil and (iv) potential effect on man and ecosystem
5. Proposed remedial measures, for example:
   Extreme risks: saving project, monitoring
   Medium risks: monitoring of wells near the landfill

Low risks : monitoring stable conditions

At the open/controlled landfills operated at the present time, we assume a safe operation according to the new Waste Act (2001), i.e. the operation without environmental risks. It was also confirmed by control sampling of two landfills: a municipal landfill and a dangerous wastes landfill.

Landfills with the highest load to the river basin are also the biggest potential threat for both surface and ground waters. The Water Act of the Czech Republic enforces, together with the European Community Directives, a general water protection; and it is a base of principles of strict and special protection of water sources, which were subjects of our research.

Closed landfills of municipal or municipal and industrial waste, resp., were selected from the database for a detailed study. These landfills were located near catchment areas. This contribution includes the results of monitoring some of them that could directly endanger the following drinking water sources:

- ground water source Třebětín, 4 $l \cdot s^{-1}$;
- ground water source Tišnov - Předklášteří, 10 $l \cdot s^{-1}$;
- catchment area Holešov, 70 $l \cdot s^{-1}$;
- gravel pit Hulín, utilizable yield 80 $l \cdot s^{-1}$;
- potential ground water source Bzenec III, 140 $l \cdot s^{-1}$; and
- ground water source Otrokovice – Kaplička, 15 $l \cdot s^{-1}$.

The research was aimed at assessment of the outflow of selected priority pollutants (heavy metals and some organic compounds) and elements affecting eutrophication, (phosphorus and nitrogen) from the landfills and at the determination of ecotoxicity of the leachates. The goal was assessment of the danger posed by the landfills to the drinking water sources.

METHODS

The available information on the studied localities is summarised in Table 1.

Table 1 Information on selected landfills

Landfill	Deposited waste	Risks
Tišnov	unknown	medium
Letovice	fly ash, slag, cinder, mineral sludge and oils, paint materials, textile, sewage sludge, municipal wastes	high
Bzenec	mineral, wooden, and municipal wastes, sewage sludge	high
Kvítkovice	municipal and industrial wastes	high
Holešov	municipal wastes	medium
Hulín	municipal and industrial wastes	medium

Samples of the leachates were taken from the monitoring bores located close under the landfill body, from the stationary stage of water level. Turbidity was removed by filtration through a paper filter.

Chemical analyses were performed according to ČSN ISO standards. The toxicity of the leachates was evaluated by a battery of tests including tests with producers and consumers:

- Thamnotoxkit F^{TM}: a 24h acute lethality bioassay, performed in multiwell test plates on instar II-III larvae of freshwater crustacean *Thamnocephalus platyurus* hatched from the cysts (Centeno *et al.*, 1995)
- Rotoxkit F^{TM}:a 24h acute lethality bioassay performed in multiwell plates on freshwater rotifer Brachionus calyciflorus hatched from the cysts (Snell *et al.*, 1998).
- Algaltoxkit F^{TM}: a 72h chronic algal growth inhibition test performed in long cells as test vials. *Raphidocelis subcapitata* remobilized from algal beads is used as test species (Persoone, 1998).
- Semi-chronic toxicity test with *Sinapis alba* (mustard): a 72h test consists in testing of effect of the leachate on germination and root elongation of *Sinapis alba* in initial development stages (Rojíčková *et al.*, 1997).

Toxicity data were calculated as EC50 (in % dilution) using the probit method and transformed to Toxicity Units (TU) with the formula TU = (1 / EC50) * 100 (Sprague *et al.*, 1965). Values of TU < 1 are expressed as TU = 0.5 in the figures.

RESULTS AND DISCUSSION

Average results of selected chemical analyses of the leachates are presented in Table 2 and Table 3. For better orientation, limit values set by the Decree No. 376/2000 Coll. specifying requirements on drinking water are given as well. Measured values exceeding these limits are set off.

With the exception of the Kvítkovice landfill, concentrations of all measured compounds in the leachates are very low. They usually only slightly exceed limits for drinking water. Overview of compounds occurring in elevated concentrations in the leachates differs at various landfills and depends on the type of deposited waste. From heavy metals; chromium, nickel, lead, cadmium, and mercury belong to this group. Slightly elevated concentrations of non-polar hydrocarbons were found in nearly all leachates. From nutrients, elevated concentrations of nitrogen in the form of NH_4^+ were found in some leachates. The concentrations of phosphorus were low.

Toxicities of the leachates are presented in Figure 2. According to the standard method of evaluation of toxicity tests results, the worst results of ecotoxicological monitoring of each landfill are given in the graph. The leachates ranged from slightly toxic to toxic. The toxic impact to the micro-algae was higher than to other test organisms. That points to chronic rather than to acute toxicity, which corresponds to low concentrations of pollutants in the leachates. The leachates from the Kvítkovice landfill containing hundreds $mg \cdot l^{-1}$ $N\text{-}NH_4^+$ were much more toxic than the other leachates. The difference in toxicity became evident in case of tests with crustaceans and rotifers (TU = 22.3 and 11.9, resp.) that are negatively affected by ammonia especially in the form NH_3. Toxicity to algae is comparable to leachates from the other landfills because algae use $N\text{-}NH_4^+$ as a source of nitrogen.

Table 2 Concentrations of nutrients and organic compounds in the leachates ($mg.l^{-1}$ except pH)

Landfill		pH	$CHSK_{Cr}$	BSK_5	$N\text{-}NH_4^+$	$N\text{-}NO_2^-$	$N\text{-}NO_3^-$	P_c
Tišnov	Average	7	19	1.3	0.98	0.05	29.12	0.37
	Range	6.9-7.2	6-33	0.7-1.5	0.29-2.04	0.00-0.22	22.7-35.7	0.30-0.42
Letovice	Average	7.0	31	3.2	1.82	0.02	2.23	0.23
	Range	6.9-7.1	7-49	2.2-4.9	0.92-2.34	0.00-0.05	0.32-4.83	0.22-0.23
Bzenec	Average	7.2	29		1.09	0.02	7.98	0.23
	Range	6.4-7.8	5-60		0.1-2.62	0.00-0.06	0.19-31.3	0.18-0.26
Holešov	Average	7.2	3		0.41	0.03	12.37	0.26
	Range	6.9-7.6	0.5-7.4		0.30-0.50	0.00-0.09	6.9-18.2	0.25-0.26
Kvítkovice	Average	7.5	280	43	659	0.60	9.78	1.21
	Range	7.3-7.9	130-257	26-60	443-830	0.00-1.8	2.2-25.1	0.46-1.74
Hulín	Average	7.1	91		8.7	0.02	0.14	
	Range	6.8-7.2	68-114		6.8-10.6	0.00-0.02	0.05-0.23	
376/2000 Coll.	Limit	6.5-9.5			0.39	0.15	11.3	

It was confirmed by a few years lasting monitoring of these old loads that the pollutant concentrations and leachate toxicities substantially dropped in comparison with landfills in operation due to maturation processes running in the landfills. Yet, they pose a risk to ground water sources that cannot be neglected. The fact that they can endanger them at favourable hydrological conditions supports the necessity of their supervision and monitoring.

CONCLUSIONS

- In the Morava River basin, there are both closed landfills (old loads) and landfills operated as prescribed by the Waste Act, which is in accord with European Community Directives. Information on the landfills is saved in a database of the Ministry of the Environment of the Czech Republic, which is continuously updated.

- Old loads were classified according to their risks. Ecotoxicity of the burdens, which endanger the ground water sources at most, was evaluated. Concentrations of monitored heavy metals and selected organic pollutants usually only slightly exceed limits set for drinking water. Most leachates show chronic toxicity.

- All research results of the Morava Project are used as given data for implementation of EC Directives into legislature of the Czech Republic in the area of wastes, water management, and the environment as such.

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Table 3 Average concentrations of selected pollutants in the leachates

	Cr	Ni	Cu	Pb	Cd	Zn	Hg	NEL	PCB*
Landfill	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$ng.l^{-1}$
Tišnov	<0.05	<0.02	0.13	<0.03	<0.001	9.03		0.65	27
Letovice	<0.05	0.19	<0.01	<0.03	<0.001	2.90		0.60	<20
Bzenec	<0.05	0.04	0.01	0.05	0.001	0.13	<0.001	0.05	32
Holešov	<0.05	<0.02	<0.01	<0.03	0.120	0.18	0.8500	0.18	<20
Kvítkovice	0.21	0.06	0.02	0.05	0.002	0.08	<0.001	0.32	80
Hulín	<0,05	<0,05	0.01	0.08	0.12	0.09	0.00	0.10	<20
376/2000 Coll.	0.05	0.02	1.0	0.025	0.005		0.001	0.05	

** Sum of congeners 28, 52, 101, 138, 153, 180*

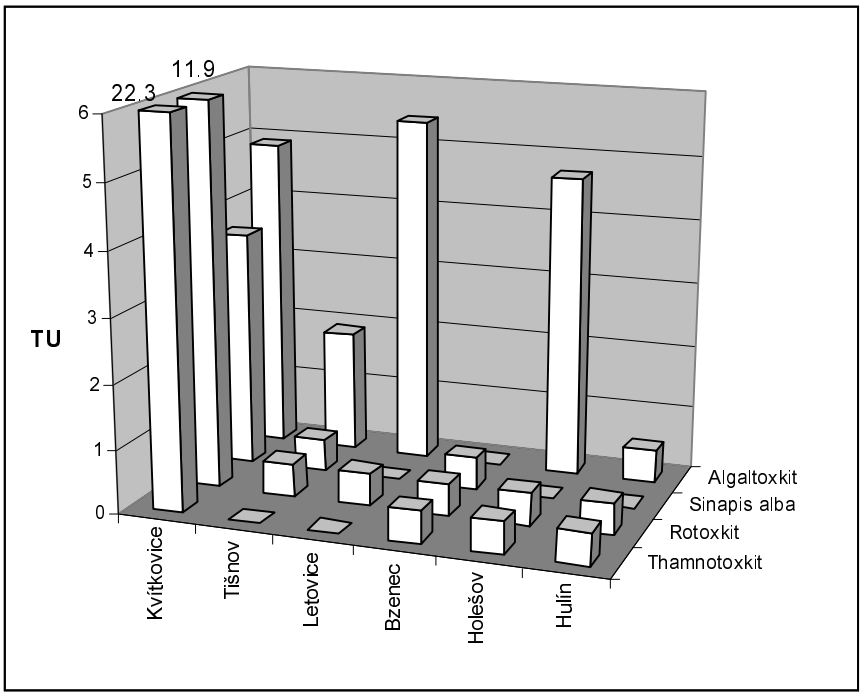

Figure 2 Toxicity of the leachates

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