RESULT OF WETLAND AND BARRIER SYSTEM PILOT TESTS FOR REMOVAL OF HCH AND CB FROM CONTAMINATED MINE WATER LEACHATE

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Abstract
The body of a former uranium mine dump is contaminated with hexachlorocyclohexane ballast isomers, which are drained into the leachate at the base of the dump. Outflowing mine water contains on average 115 ug/l of total hexachlorocyclohexane and approximately 244 ug/l of total chlorobenzene. The experimental research was carried out between 2013 and 2015 and developed possible methods for treating contamination, followed by pilot testing of the proposed systems at the site. The article presents the results of the laboratory testing and pilot testing of the systems and their effectiveness.

Key words:
wetland systems, barrier systems, biodegradation, sorption, remediation, mine water

Introduction

The remediation of the Hájek mine dump is performed by the Technical University of Liberec in collaboration with AQUATEST a.s. This collaboration began in 2013 in the framework of a contractual research project. One of the activities performed within the project was the treatment of drainage wastewater by a complex of four remedial systems. The pilot remediation system is based on research of four different remedial methods, results of experimental laboratory analysis and physical and chemical monitoring of the results. The research and the experiments focused mainly on the removal of hexachlorocyclohexane (HCH) and chlorobenzene (CB) contamination. These are the major pollutants in the drainage water. The Hájek mine dump was formerly used as an unmanaged storage of waste from the production of lindane. HCH isomers formed as side products during the lindane production. Laboratory tests were performed and a pilot system was designed during 2013 and at the beginning of 2014. The pilot system was implemented in the summer of 2014 and consists of the following four technologies (Polách et al., 2014):

System N-A – natural wetland system
System N-B – biodegradation system
System N-C – permeable reactive barrier
System N-D – sorption remediation system

System N-A is made up of a longitudinal flow reservoir measuring 12.00 x 4.00 x 0.50 m. The reservoir is filled with soil substrate (local soil: gravel in a ratio of 1:1). This is also used as a base for growing wetlands plants. The reservoir in system N-B is formed the same as in system N-A (i.e. longitudinal flow reservoir measuring 12.00 x 5.00 x 0.50 m), but it consists of two sub-reservoirs: first for anaerobic biodegradation with a filling made up of woodchips (50%), corn silage (25%) and cereal meal (25%); the second part works as classic aerobic wetland constructed the same as system N-A. The permeable reactive barrier (system N-C) consists of three interconnected 4m^3 shallow reservoirs filled with iron filings, which leads to the chemical reduction of contaminants. System N-D represents a filter body, where peat and woodchips in a ratio of 1:1 are used as a sorbent (Polách et al., 2014).

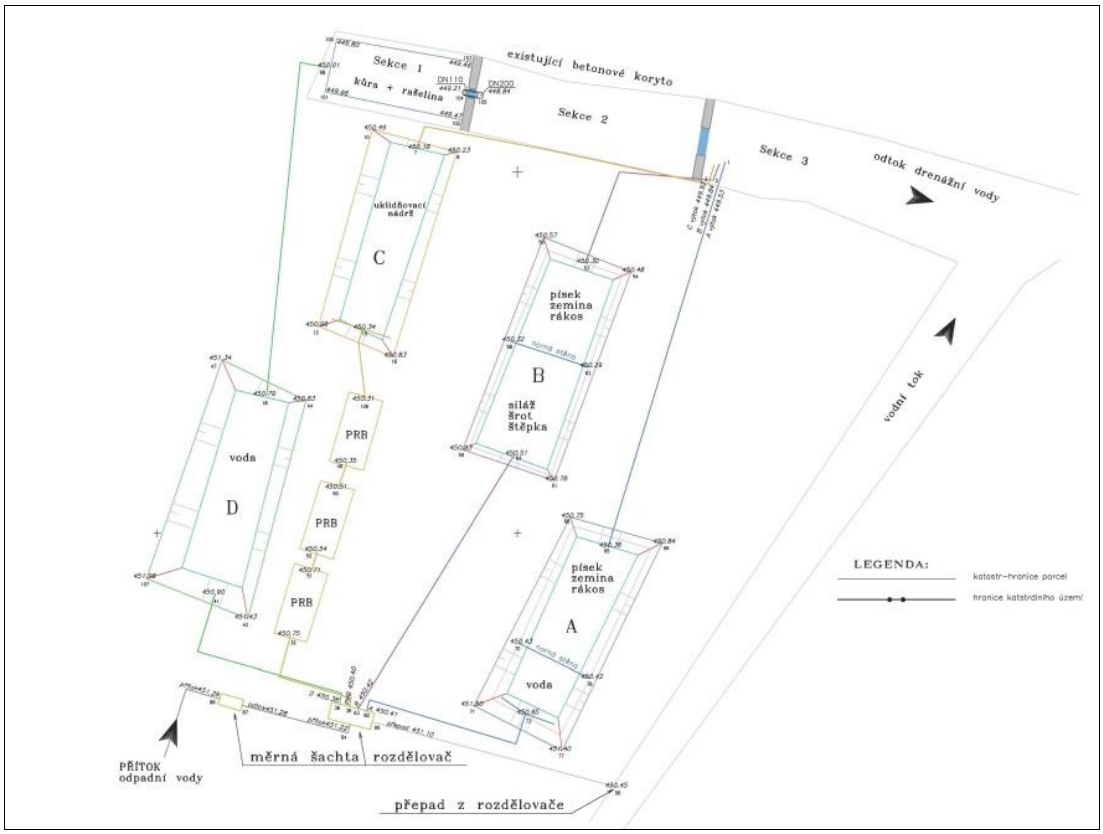

Fig. 1: The pilot system for treatment of drainage water

Methods

The evaluation of the efficiency of each system consists of an analysis of the pollutant volume in the solid component of the system fillings (sorption evaluation) and an analysis of the microbial vitalization of the fillings (evaluation of biodegradation processes). Samples of the system fillings were taken during April 2015. Two to three samples were taken from the centre of the longitudinal profile, the centre of the vertical profile and in every third/quarter cross-section profile. The samples were numbered upwardly in the water flow direction.

All of the samples were processed in the accredited laboratories of AQUATEST a.s. and the Technical University of Liberec. The GS/MS method was used for quality assessments and molecular-genetic analysis was performed using molecular biology methods (Polách et al., 2015). The acquired data were then processed to define the mass balance in each system. Based on this, the efficiency and mechanisms of degradation in the remediation systems were evaluated.

Results

For defining the efficiency in HCH and CB removal in every single system was important to quantify the mass of pollutants. A comparison of the concentrations in the input to and output from the system proved that system N-A (aerobic wetland) has a HCH and CB removal efficiency of approximately 80%, system N-B (anaerobic biodegradation) has an efficiency of approximately 72%, and system N-C (chemical reduction) and N-D (sorption on peat) both have an efficiency of 85%.

The total quantity of removed compounds was then characterized based on the processes taking place within the individual systems i.e. biodegradation, chemical reduction, sorption, or volatilization.

Biological degradation works mainly in system N-D, which has the highest biological vitalization based on the quantity of biomass. System N-B has relatively high biological vitalization. System N-A shows the third highest biological vitalization with system N-C having the lowest determined biological vitalization.

Regarding the sorption efficiency we can state that for total HCH and CB system N-A showed almost no sorption, system N-B showed significant sorption of HCH and 4x lower sorption of CB, system N-C adsorbed mainly CB and to a lesser extent HCH, system N-D adsorbed the same amount of HCH as CB, but less than systems N-A and N-B.

For an overall impression of the efficiency of each system a synthesis of the results of pollutant flow, biodegradation processes and sorption processes was performed. Based on the results of this synthesis the mass balance was calculated, which is shown in the table below.

Tab. 1: Mass balance of the removed pollutants

system	balance of removed pollutants		balance of adsorbed pollutant		difference		% biodegradated (A,B,D) or chem. reduced (C) HCH, at CB volatilization is expected	
	total CB	total HCH	total CB	total HCH	total CB	total HCH	total CB	total HCH
	g in period 08/2014 - 04/2015		g, monitoring 04/2015		g			
system N-A	144	52	0	0	144	52	**100%**	**100%**
system N-B	170	92	15	64	155	28	**91%**	**31%**
system N-C	144	87	33	2	111	84	**77%**	**98%**
system N-D	315	160	3	3	312	157	**99%**	**98%**

The results show that systems N-A and N-D only removed HCH and CB by biodegradation and partly volatilize CB. System N-C removed 98% HCH and 77% CB by chemical reduction, the rest (2% and 23%, respectfully) are fixed to the iron filings in the filter. System N-B has the highest efficiency in terms of sorption of HCH, where only 31% of the total quantity of this compound was biodegraded. On the other hand, CB was mostly removed by biodegradation i.e. 91% of the total quantity (Polách et al., 2015).

Discussion

The evaluation of the pilot systems and analysis of results did not confirm the previous expectations set for each system during the experimental and research phases. For some systems for example the expected sorption capacity of the filter (filling) was not reached i.e. system N-D. On the other side was in this system found higher biodegradation efficiency than was expected and based on experimental hypothesis. In system N-D biodegradation outweighed sorption by 100%, this means that the system originally made for sorption only adsorbed 1% of CB and 2% of HCH from the total quantity of removed pollutants. The sorption capacity of peat set in the laboratory is 20% according to the monitoring results. For system N-B we find the opposite effect i.e. the system biodegrades distinctly less and conversely adsorbs 2 to 3 times more.

Conclusion

In terms of the quantity of removed pollutants (g in the period between 08/2015 and 04/2015), we can consider system N-D as the most effective as it removed two to three times more pollutants than the other systems . These conclusions were also confirmed by recalculating the quantity of pollutants to the unit of reservoir volume (g/m^3). Here it was also confirmed that system N-D has the highest efficiency i.e. 13 g/m^3 of HCH and 26 g/m^3 of CB. Slightly less effective is system N-C and the least effective is system N-A.

The pilot tests show that a substrate made of the mixture of peat and woodchips has the highest efficiency for the complex removal of HCH and CB contamination. This system predominantly removes the contaminantsby biodegradation.

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