

## ASSESSMENT OF ANTHROPOGENIC ACTIVITY NEGATIVE IMPACT ON THE KARST LANDSCAPE AND A PROPOSAL FOR REVITALIZATION MEASURES

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**Abstract:** The paper presents the results and evaluation of the negative impacts of anthropogenic activities (agricultural activities, mechanical and chemical components flow into the underground, illegal landfills in karst depression forms of the georelief) on the quality of hydrological systems in karst landscape. In this context, the environmental research was carried out in the Važec Karst (Slovakia) during the years 2005-2007. There was found a number of illegal landfills near the Priepadla what is the main hydrological system. By remediation of the biggest illegal landfill in the Konska diera abyss were harvested 160.42 t of waste, 63.42 t were defined as hazardous waste by accreditation testing, what presents 39,53 % rates. Carried out analysis of groundwater quality in the hydrological system of the Priepadlá, which is near the Konská diera abyss were exceeded the limits, indication or recommended values according to the SR Government Regulation No. 354/2006 at water temperature, COD<sub>Mn</sub>, coliform bacteria, mesophilic bacteria and psychophilic bacteria. Old environmental burdens in the form of illegal landfills have a big impact on pollution and quality of hydrological structures in the karst areas, and also on the growth of synanthropic vegetation. The surface karst is closely linked with underground karst by mass flow, energy and information flow, creates a specific natural geosystem. In this context, we consequently present implemented measures of practical protection focused on revitalization of disturbed karst landscape. Based on the environmental situation of evaluated karst area, as priority, we propose to improve vertical co-operation in spatial planning, to improve horizontal co-ordination and karst land-integration and to develop Stakeholders' involvement (including environmental awareness increasing of local stakeholders about uniqueness and vulnerability of the karst landscape, to explain the water circulation in underground and clarify the meaning of karst).

**Keywords:** karst landscape, environmental burden, illegal landfills, Važec Karst, practical protection

### 1. INTRODUCTION

Karst systems are often extremely sensitive to the nature of human activities taking place on the surface. Pollutants and contaminants can wash into karst landforms and downward through sinkholes and fissures in the hard carbonate bedrock, rapidly entering the aquifer below. Because so much of the world's population (some sources estimate as much as 25%) draws drinking water from karstic aquifers, there is a significant incentive to understand and develop land use regulations that work to prevent the inadvertent contamination of groundwater supplies in karst landscapes. It's necessary to pay more attention to the issue of negative impact of anthropogenic activity on the karst landscape which is unstable

natural geosystem with high sensitivity to any components of intervention, because the recovery is extremely difficult to impossible. Old environmental burdens in the form of illegal landfills in the Važec Karst cause environmental problems disrupting balanced conditions, stability and biodiversity of the landscape's sphere.

Environmental burdens of old landfills and illegal landfills by their character are serious problem not only for the waste management, but also for the protection of nature and landscape. They are often characterizing as "timed chemical bombs" which pose a long-term threat not only because of underground and surface water contamination, but also in terms of their possibility of self-ignition and odorous smoke spreading, diseases spreading,

reproduction of unpleasant parasites, invasive plant's species (for example *Fallopia* sp.), growing of synanthropic flora and etc. It's also necessary note the fact that the waste's composition in the landfills is mostly unknown and people and animals have a free access to the landfills. It is dangerous to use karst's depression forms of georelief (sinkholes and abysses) for landfills formation due to the specific characteristics of the karst landscape (intensive percolation, specific underground water flow and poor filter capacity).

Negative effect of karst landscape with allochthonous water isn't rarity because water is the most dynamic transport actor of possible contamination.

## 2. MATERIALS AND METHODS

The Važec Karst (Slovakia) is a part of Koza ridges, resp. of western part Važec ridges and it also extends with a small part into the upland Hybrinska of Liptov hollow (Mazúr & Lukniš, 1978; Gajdoš & Škodová, 2009). It is among the High and Low Tatras, particularly between the cadastral area of villages Važec and Šuňava in the neighbourhood of Liptov hollow, resp. of Podtatranská hollow.

Environmental research and remediation of old environmental burden in the form of illegal waste landfills in the karst's depression form the Kónská diera abyss and the hydrological system of the Prieпадlá in Važec Karst were conducted during the years 2005 to 2007. The Kónská diera abyss and the hydrological system of the Prieпадlá presented basic sampling places.

Monitoring of groundwater quality of important underground hydrological system the Prieпадlá was realized before the remediation of illegal landfills in the Kónská diera abyss. Environmental research was focused on identification of contamination level affected by anthropogenic activities (illegal municipal waste dumps, dead animals and toxic waste) near the hydrological system the Prieпадlá. Physical-chemical components (conductivity, water temperature and pH) and microbial components (coliform bacteria, mesophilic bacteria (microorganisms cultivated at 37°C) and psychrophilic bacteria (microorganisms cultivated at 22°C) were testing in samples of the water by accredited test carried out at own testing laboratory or subcontracting accredited test. The results of analyse were subsequently compared with the limits, recommended or indication values according to the SR Government Regulation No. 354/2006 and a set the water quality class according to STN 75 7221.

Illegal landfills disposal consisted of abyss and sinkholes cleaning and followed with underground spaces disinfection with the SAVO disinfectant.

We climbed down into the abyss by a rope ladder, lightning wasn't necessary. The waste from underground was removed in the plastic 50 l containers using a small electric crane. The waste from elevator was directly transported into prepared container or tractor with a trailer carried waste, before its further handling, for temporary waste storage to the Agricultural cooperative in Važec. Consequently the waste was sorting and samples were taken for chemical analysis (determining of toxicity). According to the results of laboratory analyses assorted waste was carried in the large-capacity containers for its disposal. Based on chemical indicators and according to the Annex no.5 of Act no.223/2001 were description and identification of waste samples implemented by Accredited Testing Laboratory 3 – BEL NOVAMANN International Ltd. in Nové Zámky. In waste were evaluated quantities of selected heavy metals, chlorides, fluorides and water soluble sulphates, content of water soluble salts, extractable halogenated organic compounds and pH.

All practical protection of karst landscape measures were provided by members of Speleoklub Nicolaus with the financial support of European Structural Funds.

## 3. RESULTS AND DISCUSSION

During the one of exploratory action in the Važec Karst, the regional group of speleologists from Liptovský Mikuláš discovered illegal landfills, which were created by local citizens of Štrba, Šuňava and Važec villages for several decades. The landfills mainly consisted of municipal waste (plastic waste, cans, and glass bottles), building and hazardous waste (red, white and green chemicals in paper and plastic bags), dead animals (there were found remains of horses's, sheep's and cattle's bodies and skeletons). Identifying the producer of waste has failed in any case until now.

Sources of karst landscape degradation in the form of illegal landfills were located in the karst's depression forms of georelief (abysses and sinkholes) and karst formations (caves) of Prieпадlá, Líščie diery, Kónská diera, Výkop and Šoldovo.

Before remediation of old environmental burdens in a way of cleaning abysses, sinkholes and caves started, it was necessary to solve the financial issues (draft a project proposal through the European structural funds and its approval) and administrative requirements (a contract with the Slovak Caves

Administration, obtaining a permission to clean the plot of land from the owners – Urban community in Sunava). Illegal landfills with agricultural activities are the main factors affecting the quality of surface and ground water. At the same time, their existence occur a threat of many environmental media, including ground water.

The pollutants found in water supplies in karst areas vary depending on the local sources of contamination. The most common problem is contamination by micro-organisms from human or animal wastes.

Coxon (2011) states that farm wastes and sewage can also give rise to chemical pollutants including nitrate and ammonia. In some cases, an unusually high level of a chemical constituent (e.g. chloride, potassium), though not in itself harmful, may indicate a pollution problem. Excessive iron and manganese are causing taste or staining problems, may occur naturally, but may also be released from the soil or rock into water supplies by pollution, particularly by silage effluent pollution. Sheep dip which is incorrectly disposed of may pollute water supplies with phenols and a range of potentially harmful pesticides. Leaking fuel tanks can contaminate groundwater with a range of hydrocarbons which will cause taste and odour

problems and can cause a health risk, even at very low concentrations.

#### • The Kónská diera abyss

The Kónská diera abyss reaching a depth 16 m, is located in the Važec Karst on the east from the Líščie diery, on the eastern side of Sýkorov vršok (943 m) (Fig. 1). It belongs to the basin river of Biely and Čierny Váh from the view of the hydrographical sites. Limit the geographic river basin is not identical to the hydrological. In view of the propensity of limestone layers to the north resp. to the east, karst plateaus Mura and Krieslo belong to the geographical basin Čierny Váh, which are drained by a system of sinkholes and karst cracks in the valley of the Biely Váh.

Thus hydrologic basin of the Biely Váh deeply intervene into geological basin of the Čierny Váh. It is located on the east, 1 km from the important underground hydrological system the Priepadlá. Negative anthropogenic impacts in the Važec Karst are especially presented by illegal landfills (municipal waste and dead animals); while in the past there was also toxic waste dumping. Anthropogenic burden of geosystem in the Važec Karst is also related to groundwater pollution from agricultural activities, cattle grazing and sheep grazing, mechanical and chemical mass flow into the underground.

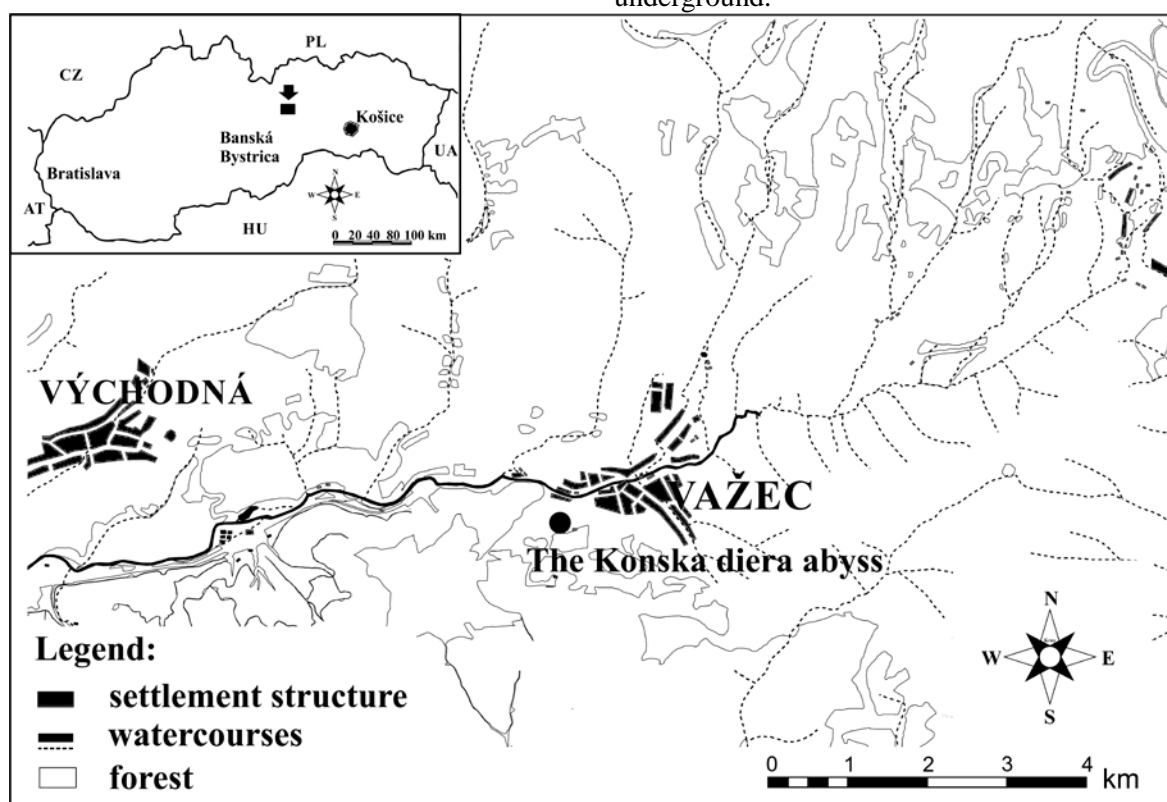


Figure 1 Localization of the Kónská diera abyss

This leads to pollution of all important hydrological structure the Priepadlá. Hydrological trace test of hydrological system the Priepadlá – the Teplica spring. Time of appearance of the indicator in the Teplica spring from its application to the main cave dive at the Priepadlá lasted for 14 hours at overcoming distance (direct distance) 3 km with an elevation of 90 meters (assumption of a large cave system).

The Kónská Diera abyss is named after the fact that during the research and measuring in 1961 there was found a large amount of horse's bones at its bottom. Inconspicuous hole of abyss with measure of 2 + 4 m is lying in height 933 m above the sea level. A hole of the abyss has a shape of the well's sinkhole that getting narrow to 1.3 m at a depth of 2 m and leads with nearly vertical stack to conical house's space. A debris cone of limestone's boulders up to 3 m is under the stack at the bottom of abyss. The bottom of abyss has an elliptical shape, oriented with longer axis to the WNW – ENE. It reaches length of 16 m and width of 8 m (Droppa, 1962). The local population had known a surface hole of abyss for a long time and they used it as a place for disposal of dead animals.

Monitoring of water quality of important underground hydrological system the Priepadlá closely situated to the Kónská diera abyss was realized before the remediation of illegal landfills in the Vážec Karst. The Kónská diera abyss and hydrological system the Priepadlá belong to the basin of rivers Biely and Čierny Váh in the view of hydrological sites. Physical-chemical and microbial analyses were focused on identifying possible negative environmental burden of the Vážec Karst by anthropogenic activities impact (illegal municipal waste dumps, dead animals and toxic waste) near the hydrological system the Priepadlá. Water samples were tested of selected physical-chemical components (conductivity, water temperature, pH and COD<sub>Mn</sub>) and microbial components (coliform bacteria, mesophilic bacteria and psychrophilic bacteria). The results of laboratory analyses are

presented with the water quality class according to STN 75 7221 in the table 1.

Results of research confirm the organic pollution of evaluated hydrological system as a consequence of negative impact of anthropogenic activities in the Vážec Karst when crossing the measured values of selected physical-chemical components and microbial components; the limit, recommended or indication values were exceeded according to the SR Government Regulation No. 354/2006, and reduced water quality class.

Work on cleaning of the Kónská diera abyss started on 5th June 2006. At first, two covering panels obscuring the entrance into the abyss were uncovered. It was necessary to fence in and properly mark the whole work place. Hazardous waste (chemicals of red, green and white colour) found right after uncovering the panels was packed in the plastic and paper bags. After pulling up, the waste was placed in the watertight plastic barrels with lids. Other removed waste was collected in a portable steel container near the mouth of abyss. After climbing down to a depth of 4 m, in the point of simplifying the work, as well as safety reasons, were built a scaffold with a platform which were covered with the plastic tarpaulin to prevent entering of rain water into the ground and to make a possibility to work in a bad weather.

In the composition of waste from a depth of 6 meters, started dominate old cans, construction waste along with skeletons of animals, particularly of horses, sheep and cattle. In a few years people had thrown there a large number of dead animals (there were counted at least 15 units of cattle). For climbing down into deeper parts of the abyss was used cast-iron ladder and if it was necessary, was supplied according to an increasing depth. To avoid of falling down, the cave's team was secured with climbing rope during climbing down to the underground.

Removing the risk of microbial pollution in vulnerable karstic areas requires two complementary approaches.

Table 1. Contents of selected physical-chemical and microbial components in water, hydrological system the Priepadlá

	Unit	Measured value	Class of quality according to STN 75 7221
conductivity	µS/cm	588	II.
water temperature	°C	9.1**	I.
pH	without unit	7.6	II.
COD <sub>Mn</sub>	mg/l	4.3**	II.
coliform bacteria	KTJ in 100 ml	811**	
mesophilic bacteria	KTJ in 1 ml	514**	
psychrophilic bacteria	KTJ in 1 ml	1274**	

\*\* - exceeded the limit, recommended or indication values according to the SR Government Regulation No. 354/2006

Table 2 Contents of selected chemical components in waste, The Kónská diera abyss

Indicator	Unit	Measured value	Measurement uncertainty*	Evaluation	TT
Arsenic	mg/kg dry biomass	0.095	-		SA
Barium	mg/kg DB	0.29	0,075		A
Cadmium	mg/kg DB	0.0038	-		SA
Chromium	mg/kg DB	0.21	-		SA
Copper	mg/kg DB	0.3	-		SA
Mercury	mg/kg DB	<0.001	-		SA
Molybdenum	mg/kg DB	<0.3	-		SA
Nickel	mg/kg DB	<0.05	-		SA
Lead	mg/kg DB	0.11	-		SA
Antimony	mg/kg DB	0.017	-		SA
Selenium	mg/kg DB	<0.01	-		A
Zinc	mg/kg DB	1	-		SA
Water soluble chlorides	mg/kg DB	<40	-		SA
Water soluble fluorides	mg/kg DB	<1	-		SA
Water soluble sulphates	mg/kg DB	206	-		SA
Dissolved organic carbon	mg/kg DB	24.9	-		SA
Soluble salts content	mg/kg DB	2400	-		A
pH	without unit	7.98	-		A
Extractable organic halogen compounds	mg/kg DB	499	42	US	A

Explanations:

TT - type of test

A - accredited test carried out in own testing laboratory

SA - subcontracting accredited test

US - unsatisfying

\*- expanded uncertainty is determined with a coefficient  $k = 2$  (the 95 %), does not include sampling uncertainty.

It is usually impossible to exclude all faecal micro-organisms, so the water supply must be treated to remove them, e.g. by filtration and treatment with chlorine, ozone or ultra-violet radiation. However, these treatment systems may fail occasionally (e.g. inadequate dosage of chlorine, suspended sediment interfering with ultra-violet treatment). For these reasons, the work on cleaning was completed by abyss disinfection with solution of SAVO and subsequently fencing around. During remediation of this illegal landfill and by cleaning of the Kónská diera abyss, was pulled 63.42 tons of hazardous waste and 97 tons of municipal waste and dead animals from the underground. The results of waste chemical analyses are presented in table 2. Based on presented, it is important to keep the raw water supply as uncontaminated as possible by controlling sources of faecal pollution. According to environmental exposure in Central Slovakia by Drimal et al., (2010) is the study of their distribution in nature is very important. Especially on the karst landscape, this is very sensitive on anthropogenic activities. Prevention is better than cure! In the autumn, after cleaning, disinfection and fencing of abyss were planted trees in front of the abyss in order to avoid access of cars to the abyss and to prevent the re-contamination.

Another negative anthropogenic interventions occurring in a given area, as we have already mentioned, are related to the dumping of hazardous and municipal waste into the sinkholes of the Vážec Karst, what besides can cause excepting local pollution also synanthropic vegetation growth. The vegetation is also extending at the bottoms of sinkholes with pouring liquid manure and organic residues runoff from the surrounding fields. Underground karst represents a specific dimension of karst landscape, which is through the water closely connected with surface karst, mass flow, energy and information and creates a specific natural geosystem.

Therefore, anthropogenic interventions in surface landscape are not negatively affected only on surface of karst, but are also manifesting in cave's, respectively in underground geosystem. For these reasons, it is necessary to use a more comprehensive approach for negative anthropogenic interventions assessment and their impact on karst landscape to solve environmental problems. Based on the above, we suggest other main principles of integrated karst landscape management:

- to improve vertical co-operation in spatial planning

The necessity of close co-operation

of administrative units is an aspect of key importance. The first condition of a successful co-ordination is undoubtedly effective communication: exchange of information, usually by talking or writing, but today increasingly through electronic media. Good communication keeps people in the picture; provides opportunities for dialogue, for discussing and resolving problems; and helps to attract and sustain interest to get things done. Successful communication means far more than a formal exchange of formalities. This is why experts are united in the opinion, that formalized authority cooperation is not enough for successful integrated karst landscape management (IKLM). IKLM depends to great extent on the voluntary measures such as communication skills to win and sustain the trust and mutual confidence of a wide range of coastal stakeholders. Stakeholders too, require the capacity to present and defend their points of view, but also, more profoundly, to listen to the rationales of others and make compromises. The most important precondition here is to be the general air of openness and partner-like relationships within stakeholders.

- to improve horizontal co-ordination and land-karst integration

Experts agree that the sustainable development of the karst landscape areas cannot be achieved solely from top to bottom (without the involvement and support of the local communities). Therefore, it is necessary in region:

- to foster ecological literacy: environmental knowledge,
- interdisciplinary bridging of earth, life, human sciences and the humanities, is particularly well suited to promote understandings of the environment as a system of interdependent parts, consistent with the new paradigm of earth and environmental sciences (the Earth System approach).

- to develop Stakeholders' involvement

Stakeholders' involvement is a generic term containing the multiplicity of terms such as e.g. 'public participation', 'public consultation', or 'citizen consultation' etc. Stakeholder in this meaning is anyone having a 'stake' i.e. interest in the management plan, either as a civil person or a group e.g. society, club, company (Zelený, 2010). Another important step in the protection of the Važec Karst must be prevention. We consider that the most important is intensifying of different ways the awareness of local stakeholders in affected municipalities (Štrba, Važec and Šuňava) about uniqueness and vulnerability of the karst landscape located in their area. It is necessary, to present in an

appropriate form as exhibitions, lectures and information boards, not only negative interventions of anthropogenic activity and its consequences in the Važec Karst, but also to explain the water circulation in underground and clarify the meaning of karst in mentioned sub – tatra municipalities, not only to farmers and the general public but especially to school-age youth.

According Buijs et al., (2013) and Vološčuk (2008) in recent years, ecosystem management and recreation have become closely intertwined. Ecosystem management influences recreational opportunities and the attractiveness of natural areas, so nowadays local communities are often invited to participate in decision-making about it. And in some cases, local communities object to ecosystem management measures. They argue that analysing these phenomena as practices can reveal how they mutually influence each other. However, acting on the interdependencies of the economic, environmental, and social justice elements of our world requires new ways of thinking about things and taking action systemic instead of symptomatic that will create a future where human society and nature can coexist with mutual benefit and where the natural resource abuse is eliminated (Flint, 2013; Švajda, 2008).

#### 4. CONCLUSIONS

The results of laboratory tests indicate a negative impact of anthropogenic activities associated with the illegal landfills, which are located near the main hydrological system in the Važec Karst. Chemical analysis of waste confirmed findings of pesticides (especially DDT), laboratory poisons and fertilizers with a toxic character. However, there are other negative anthropogenic interventions in the observed area. Hydrological tending part of the valley with hilly character in Važec Karst has been quiet intensively cultivated not only in previous years, but also in the present. For this reason, it's necessary to create "Landscape management program" based on the importance of grassland ecosystems in karst areas, which are also important for biodiversity conservation. They are communities corresponding to the specific natural relation, maintaining valuable types of communities with protected, endangered or important fytogetic species. A function of grassland is often irreplaceable in the areas that require protection. Within the management implemented in these areas also livestock breeding on pastures has recorded a renaissance in the last few years. In terms of grazing application in the karst area, where is always biodiversity maintaining in the grazing area a priority

is the most important to set an optimal grazing burden of these areas and to avoid any undesired vegetation changes of protection as a result of excessive re-grazed area burden. In this context, it's necessary to point to a fact that livestock breeding on pastures in the karst area has a specific character, because its priority is a stabilization of the site corresponding biocenosis. In this context, it is necessary to pay attention to a different protection and agricultural view, which can often, leads to misunderstandings in the karst landscape management. In these contexts, it can be concluded that in the protection of this unique area, agriculture will play an important role over the long evolution of the Važec Karst region. As the protection of surface and underground karst phenomena of the karst landscape and biocenosis bounded to it, is possible only in relation to the intensity reduction of anthropogenic activities from agricultural activities (in conjunction with the grassing), we suggest following principles to be observed for agricultural land use: the cultural plots will be managed by current way, meadows and pastures will not be transformed in the arable land or others categories of agricultural land sources with the exception of the forest ecosystems, wetlands will not be irrigated.

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