The problematics of cave pollution in Bela krajina

Problematika onesnaženosti jam v Beli krajini

Daniela RIBEIRO & Jure TIČAR, Geografski inštitut Antona Melika ZRC SAZU, Gosposka ulica 13, SI-1000 Ljubljana; E-mails: daniela.ribeiro@zrc-sazu.si, jure.ticar@zrc-sazu.si

According to the Underground Cave Protection Act (Ur. l. RS 2004), caves in Slovenia are defined as natural heritage of national importance and are owned by the state. The law defines the activities in caves, mostly outlining the prohibited impacts on cave environment. Some regulations have also been applied for tourist activities, due to the commercial use and adaptation of the show-caves inventory (Ur. l. RS 2004). Although the legislation strictly prohibits the pollution of caves in any form, monitoring and remediation activities are not officially being practiced. Nevertheless, some caves have been cleaned up in the past, mostly on the initiative by cavers (Prelovšek 2011).

Anthropogenic impacts on caves were quite common already in the past, when used for residence, shelter, religious ceremonies, extraction of natural resources and tourism. However, with the socio-economic development, the emergence of unusable household waste and the unregulated waste management, the pressures on caves led to the increase of cave pollution in Slovenia, especially after World War II (Prelovšek 2011). Subsequently, it has been estimated that around 20% of caves in Slovenia are polluted, especially in the lower karst areas close to the settlements (Čekada 2015).

Several studies have already shown the problematic of communal landfills in karst areas of Slovenia, which greatly contribute to contamination of karst waters (e.g. Kogovšek & Petrič 2007, 2010). Beside communal landfills, illegal waste disposal is problematic in karst areas, due to their vulnerability and low self-purification processes (Ford & Williams 2007). Waste dumped in caves is washed by precipitation into groundwater, and once the groundwater is contaminated it is very difficult to remediate it (Kaçaroğlu 1999). Due to the quantity, toxicity and poor degradability of the dumped waste, practically none of the karst springs can be used for water supply without prior additional physical or chemical processing. This type of pollution is threatening the cave biota and at the same time poses a threat to the public health (Prelovšek 2011).

Cave pollution is negatively affecting the groundwater dependent ecosystems important for the survival of species (Mezga et al. 2016). In the long term, it might cause decline of one of the most important symbols of the subterranean biodiversity, the white olm (*Proteus anguinus anguinus*), as well as the black olm (*Proteus anguinus parkelj*), cave-dwelling tube worm (*Marifugia cavatica*) and troglobiotic 'living fossil' bivalve (*Congeria kusceri*). *Proteus anguinus* is endemic to Dinaric karst (Sket 1997), whereas the subspecies *P. anguinus parkelj* is known as an endemic of Bela krajina (Sket et al. 2003). Cave pollution can also indirectly affect the surface biodiversity, affecting the species that are groundwater dependent, such as the European pond turtle (*Emys orbicularis*), the presence of which was reassessed in Bela krajina (Vamberger et al. 2013). Even though the habitats of endangered and endemic species are included in the Natura 2000 network and the main aim of the Natura 2000 Management Programme for Slovenia is to ensure a favourable conservation status of Europe's significant species and habitat types (Vlada RS 2015), many polluted caves are also found within Natura 2000 sites.

The prime aim of this study was to find the main drivers of cave pollution/degradation, which can provide important data for the identification of potential effects on species, habitats and even public health in Bela krajina.

Bela krajina is located in the southeast of Slovenia and covers around 600 km^2 (Plut 2008). The central part of the region is characterized by the low area of the Črnomelj Plain that is surrounded by the hilly terrain of Gorjanci, Kočevski Rog and Poljanska gora. Due to the predominance of limestone and dolomite rocks, most of the region is karstified. The hilly terrain is characterized by the presence of distinct pits and shafts with an abundance of springs at the foothills, while on Črnomelj Plain horizontal caves prevail (Stepišnik & Natek 2014, Cave Registry 2016). The share of Natura 2000 network in Bela krajina is around 46% (Hudoklin 2014).

With more detailed analysis, we studied the distribution of polluted caves in the region of Bela krajina, their interdependence with the proximity to roads, proximity to settlements, proximity to water sources and land-use types.

Data on caves was obtained from the Cave Registry (2016), which includes location, type of entrance and state of the cave. Road infrastructure data were obtained at The Surveying and Mapping Authority of the Republic of Slovenia (GURS 2014), the same as data on selected buildings with potential waste production (GURS 2015). Land use data was acquired at the Ministry of Agriculture, Forestry and Food (MKGP 2016).

Using ArcGIS (ver 10, ESRI 2010), with the operation »Near«, we calculated the shortest Euclidean distance between caves and roads, as well as between caves and potential producers of waste (e.g. buildings, industries, and restaurants). We identified the land use type where the cave was located, and assessed the relationship between cave state (polluted, destroyed or clean) and cave entrance (horizontal or vertical entrance).

According to the Cave Registry (2016), 622 caves were registered in Bela krajina by 2015, of which 118 were defined as polluted and/or destroyed. We categorized the caves according to the estimated volume of waste: 55 low polluted (0.1–0.9 m^3), 19 medium polluted (1.0–4.9 m^3), 35 high polluted (more than 5 m^3) and 9 destroyed (not accessible anymore). The total amount of waste in affected caves in Bela krajina is estimated at around 1,000 m^3. The results show that the 10 most polluted caves (Tab. 1) hold more than 60% of all waste. Polluted caves are especially problematic in the catchment areas of springs and the areas under protection of Natura 2000. For example, 13 polluted caves are located within the catchment area of the Dobličica spring, which poses as the main water supply for the region. Overall, we identified 70 polluted and 3 destroyed caves within Natura 2000 sites.

The results of the GIS analysis revealed that clean caves are more distant from roads or settlements than the polluted ones, so we assume that these two indicators have high impact on the pollution of caves. The trend is even more obvious within the subcategory of medium polluted caves, where the distance from the roads and settlements diminishes with the increase of the amount of waste in the caves. According to the results, land use is also one of the relevant drivers of cave pollution. The share of polluted caves is higher in forests (73%) than in other land-use types: woodland (9%), grasslands (9%), urban areas (3%), extensive orchards (3%) and abandoned farmland (3%).

We noted differences in the relationship between cave pollution and type of cave entrance. Caves with vertical entrances are usually more difficult to reach by local people, and are thus mostly limited to cave explorers. Nevertheless, these sites present a favourable hidden locality for illegal waste disposal.

To conclude, this study shows which caves are more polluted and therefore pose a threat to both the environment and public health. Hence with this research, we intend to draw attention and raise awareness of the general public for the problems associated with cave pollution in Bela krajina.

Table 1. List of the ten most polluted caves in Bela krajina (source: Cave Registry 2016).
Tabela 1. Seznam desetih najbolj onesnaženih jam v Beli krajini (vir: Kataster jam JZS 2016).

Reg. no.	Name of the cave	Municipality	Estimated amount of waste [m^3]
2356	Jama pri Vranovičih	Črnomelj	100
3947	Brezno Planina	Črnomelj	100
854	Kadiševa jama	Metlika	100
853	Kipina jama	Metlika	100
8006	Brezno v Vogrju	Črnomelj	50
6676	Jama dobrega pajka	Črnomelj	50
9751	Brezno nad Jugorjem	Metlika	50
10312	Brezno 1 v Koprivni dolini	Črnomelj	50
5217	Kotlovnica	Črnomelj	32
9612	Sikara	Črnomelj	30

References

Cave Registry (2016): Cave Registry of Slovenian Caves, ver. March 2016. Speleological Association of Slovenia, Ljubljana.

Čekada M. (2015): Kraljestvo smeti – več kot 2000 onesnaženih jam v Sloveniji. Jamar 7: 53-53.

Ford D., Williams P. (2007): Karst hydrogeology and geomorphology. John Wiley & Sons, Chichester, 562 pp.

GURS (2014): Zbirni kataster gospodarske javne infrastrukture. Geodetska uprava RS.

GURS (2015): Register nepremičnin in Kataster stavb. Geodetska uprava RS.

Hudoklin A. (2014): Natura 2000 in Bela krajina. In: Štangelj M., Ivanovič M. (Eds.), Natural heritage of Bela Krajina, Slovenia. Belokranjski muzej, Metlika, pp. 53-61.

Kaçaroğlu F. (1999): Review of groundwater pollution and protection in karst areas. Water Air Soil Pollut. 113(1): 337-356.

Kogovšek J., Petrič M. (2007): Directions and dynamics of flow and transport of contaminants from the landfill near Sežana (SW Slovenia). Acta Carsol. 36(3): 413-424.

Kogovšek J., Petrič M. (2010): Tracer tests as a tool for planning the monitoring of negative impacts of the Mozelj landfill (SE Slovenia) on karst waters. Acta Carsol. 39(2): 301-311.

Mezga K., Janža M., Prestor J., Koren K., Šram D. (2016): Groundwater dependent ecosystems – groundwater status indicators. Nat. Slov. 18(1): 35-42.

MKGP (2016): Land use data. http://rkg.gov.si/GERK/ [accessed on 15. 9. 2016].

Plut D. (2008): Osnovne geografske značilnosti Bele krajine. In: Plut D. (Ed.), Bela krajina in Krajinski park Lahinja. Znanstvena založba Filozofske fakultete, Ljubljana, pp. 9-24.

Prelovšek M. (2011): Pollution and cleanup of karst caves in Slovenia. In: Prelovšek M., Zupan Hajna N. (Eds.), Pressures and protection of the underground karst – cases from Slovenia and Croatia. Karst Research Institute ZRC SAZU, Postojna, pp. 101-111.

Sket B. (1997): Distribution of *Proteus* (Amphibia: Urodela: Proteidae) and its possible explanation. J. Biogeogr. 24: 263-280.

Sket B., Gogala M., Kuštor V. (2003): Živalstvo Slovenije. Tehniška založba Slovenije, Ljubljana, 664 pp.

Stepišnik U., Natek. K. (2014): Geomorphological characteristics of the Bela Krajina Plain. In: Štangelj M., Ivanovič M. (Eds.), Natural heritage of Bela Krajina, Slovenia. Belokranjski muzej, Metlika, pp. 37-39.

Ur. l. RS (2004): Zakon o varstvu podzemnih jam. Uradni list RS 2: 165-175.

Vamberger M., Govedič M., Lipovšek G. (2013): Prispevek k recentni razširjenosti, ekologiji in varstvu močvirske sklednice *Emys orbicularis* (Linnaeus, 1758) v Beli krajini (JV Slovenija). Nat. Slov. 15(2): 23-38.

Vlada RS (2015): Program upravljanja območij Natura 2000 (2015-2020). Vlada RS, 30 pp. http://www.natura2000.si/fileadmin/user_upload/LIFE_Upravljanje/PUN__ProgramNatura.pdf [accessed on 2. 3. 2017].