OIL SPILLS IN KARST: FOUR CASE STUDIES FROM SLOVENIA

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Summary
This paper presents four case studies of oil spills that happened in the last decade on the karst surface in Slovenia. The analyses of these accidents include observations made underground and at several karst springs in the region, allowing researchers to identify the impact of spills on karst underground and especially on karst water. Comparison of discharge and oil concentration in water shows that it may take a very long time, tens of years, before all the oil is washed out of the underground. When looking for oil traces, some dry caves nearby the oil spill were visited and very high concentrations of oil were discovered in some pools of percolation water. These cannot be the result of the observed accident spills.

Introduction

In the last decade some accidental spills of mineral oils into karst underground happened in Slovenia. The present article deals with four of them. Maybe these are not the four greatest, as it is difficult to decide what is the »greatest« pollution, but they met with a wide response in public as the pollution of karst water was well visible and at the same time these are the cases, that were relatively well studied and there are data interesting also from the karst hydrology point of view. It is also important that at studies of the consequences of these accidents the members of the Karst Research Institute took part. Another reason to present the chosen cases was the fact that they happened in various types of the Slovene karst. All the treated events took place on the Dinaric karst; the accident that took place near Kozina lies almost at the border, in the region called Kras. The second location was Obrov, where typical karst of Istria lies. Other two accidents happened on the karst of Dolenjsko region where an important part lies in dolomites and on contact karst, on the contact between Palaeozoic and Tertiary silicates with Mesozoic carbonate rocks.

The spill of fuel oil in the KEKO factory (Žužemberk)

The small town Žužemberk lies in the central part of the Krka valley, which is the biggest among rare superficial rivers crossing the karst of Dolenjsko. The valley consists of two parts. The base is a wide bottom in carbonate rocks (mostly Mesozoic dolomite) bordered by higher, up to 100-m high karst plateaux, consisting of Mesozoic limestones. Into this surface of the wide »older valley«, levelled in rough but very karstified in detail, is incised a »recent« canyon of the Krka river, some 10 m deep. The karst hydrology had adapted to this morphology. Karst springs that rise far off the Krka cut their own narrow valley to reach the river; but most of the karst springs are located close to the river, on the

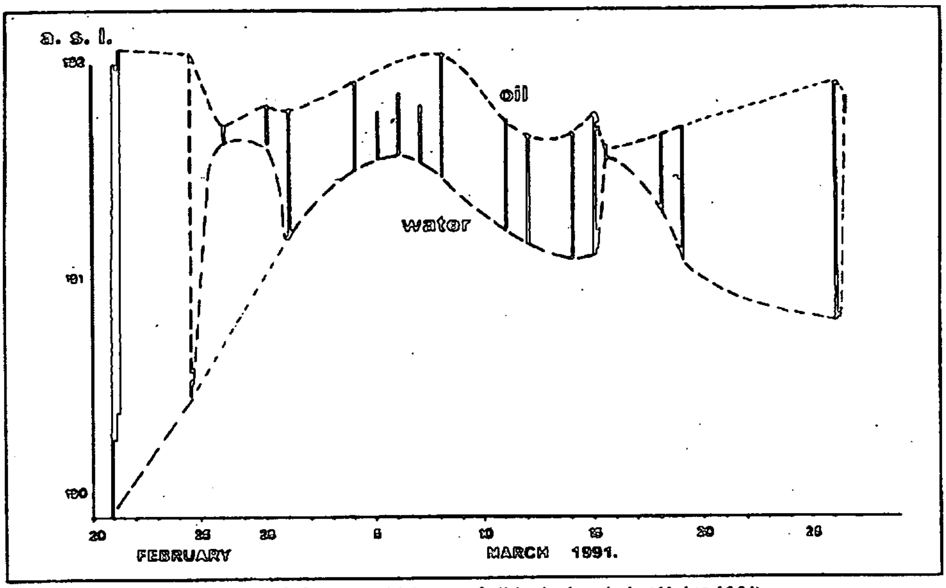

Fig. 1 KEKO factory – thickness of oil in the borehole (*Habič 1991*).

same level; in some places low waters completely flow into the springs near the river, while high waters take their springs at the border of higher lying valley and superficially flow into the Krka. A natural curiosity of the Krka is also travertine dams that appear upstream near the Žužemberk town (*Kranjc 1997*). The Keko factory is located on the mentioned upper terrace, some 100-m distant from the river. Below the edge of the steep level above the canyon there are two small karst springs; one was captured for the local water supply. After some 10-m of flow the streams join the Krka river.

In 1991 from the leaking cistern near the factory about 30 m^3 of fuel oil drained directly into the karstified rock. Shortly afterwards the fuel oil appeared in both springs but in a small quantity. With floating dams it was thus possible to prevent wider pollution of the Krka river and even the fishes survived. Regarding the quantity of oil, 30 m^3, it was presumed that a complete cleaning of the underground will last five years at least (*Habič 1991*). In the recharge area of the spring was drilled a borehole, 40 m deep, to find out what happened with this oil underground and if there was any possibility to pump it out. It was stated that oil accumulated underground in a relatively isolated oil spot. At the beginning (in 1991) the oil layer in the borehole was few metres thick (*Fig. 1*) and one part of it, unfortunately a smaller one, was possible to pump out. After four years (in 1995) the oil layer was still 62 cm thick (*Kogovšek 1995; 1996*). To August 1999, in 8 years by quite primitive techniques, 4 t of oil was pumped out from the boreholes. Nowadays the thickness of oil in the borehole reached about a quarter of a metre.

This case clearly shows that relatively great amount of oil may cause a relatively small pollution, but oil remains underground for a long time and its runoff is very slow. In this case the spring pollution had not a »catastrophic« dimension but we may say that pollution is »permanent«.

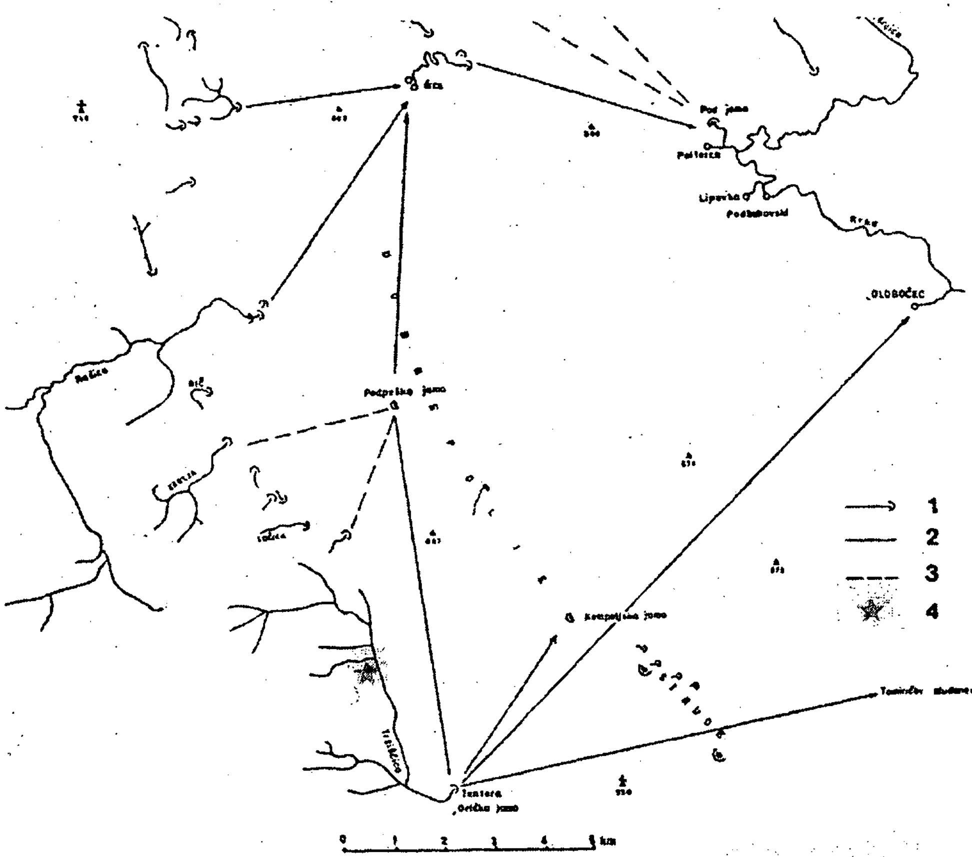

Fig. 2 Underground water connections in the Krka river springs catchment area (*Novak 1985*)
(1 – ponor, 2 – traced water connections, 3 – supposed water connections, 4 – location of the oil spill.)

The case of Globočec spring

In the north-eastern Dolenjska, near Ortnek village are located hills consisting of Triassic and Palaeozoic impermeable rocks surrounded by carbonate rocks. In these hills several streams rise and they sink at the contact with karst. The largest stream is the Tržiščica, flowing superficially to the northern part of the Ribnica Polje and disappearing into the Tentera cave. Water tracing confirmed that waters from the Tentera swallow-hole reappear in the karst spring named Globočec, 13,5 km distant (*Fig. 2*). The spring is located in a relatively deeply incised steep head valley, 1 km from the Krka. As this is an abundant spring (medium discharge 1-1,5 m^3/s) lying in the middle of the low waterless plateau called Suha Krajina (Dry Carniola) it was captured for a regional water supply in 1936 already.

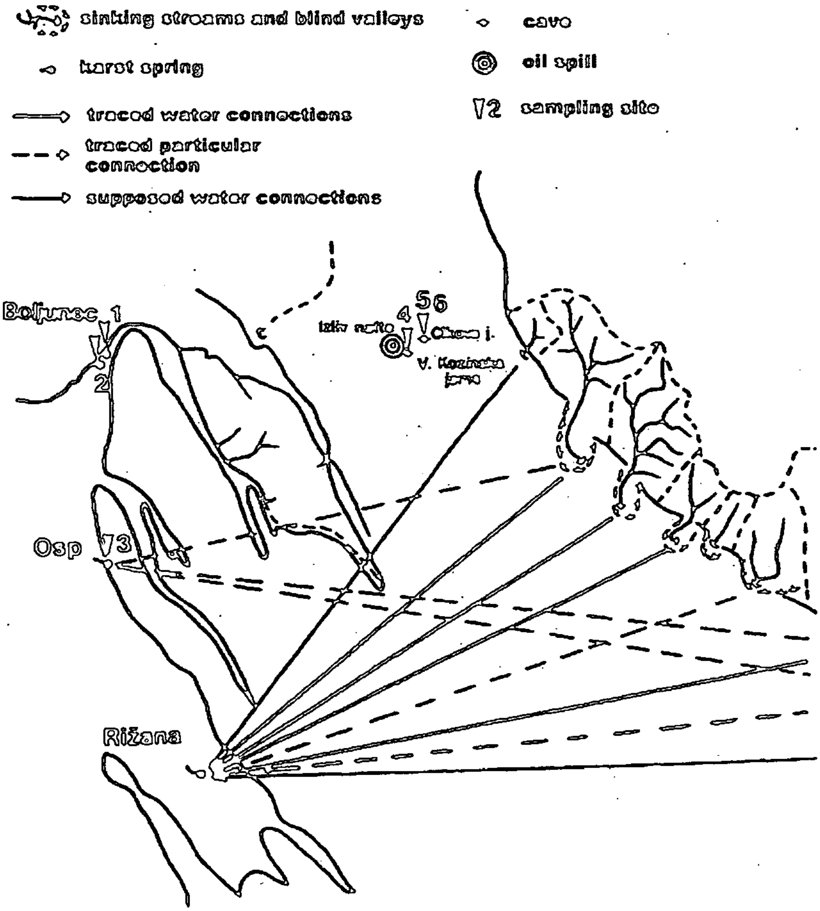

Fig. 3 Underground water connections in the Rižana karst spring catchment area (*Knez et al. 1994*).

In the village of Ortnek there is an enterprise having the storehouse for mineral oils. Owing to the break of a centrifugal pump, probably 1000 l of oil leaked out of the pump in October 1998. The workers recovered 800 l, but additional „undefined" quantity of oil ran out in the neighbour room (flooded by heavy rain) and together with water to drainage channel and to the stream Tržiščica. From the stream firemen took off 300 l of oil and water mixture. On the distance of 5 km they installed 5 barriers with absorptive material, but the oil pollution got on downstream (*Fajfar & Dolenc 1998*). The pollution reached the spring Globočec in approximately 70 hours, which gives relatively high surface and underground velocity – 7,3 cm/h. And, of course, the water supply from the spring for all the region had to be stopped, once for ten days, and second time for two weeks. The inhabitants had to be supplied with water by firemen.

Oil spill by Kozina

In October 1993 a road tanker tipped over from the main road Ljubljana – Koper near Kozina. Kozina lies off the south-eastern border of the region Kras near the edge of the plateau (about 500 m a.s.l.) above the lower coastland. 18 t of oil and fuel oil run out, and

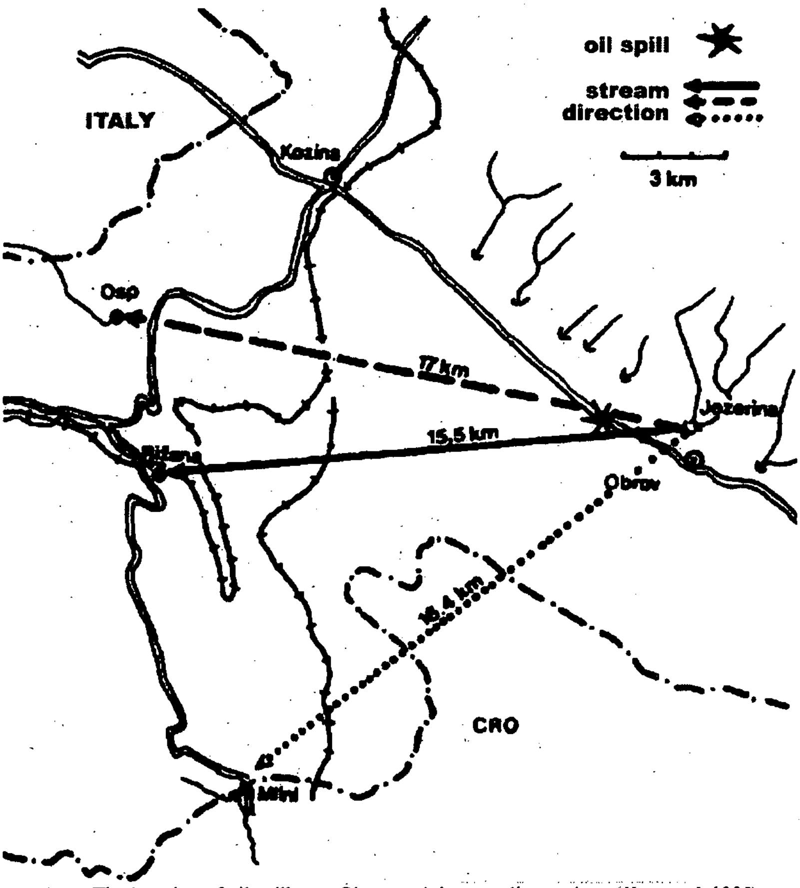

Fig. 4 The location of oil spill near Obrov and the sampling springs (*Kogovšek 1995*).

down the slope of a doline near the road. Even before the oil reached the bottom of doline it sinks into karst underground. The surface of the dolines slope is covered by grass and bush on the thin soil cover. The sinking capacity (of oil) of the slope was reckoned to be about 15 l/s. Six karst springs were observed due to detect the reappearance of the oil, between them three important ones near Bagnoli (Boljunec) on the Italian side of the border, the Osapska Reka and springs of the Rižana river, distant from 7 – 10,5 km (*Fig. 3*). All the three are direct tributaries of the Trieste Bay. The Rižana is the main water supply for the whole Slovene Adriatic coast region. The spill happened in Palaeocene limestones. Between the spill point and the mentioned springs there are bands of impermeable Eocene flysch, but the water passed under them through the limestones, as was known already according to previous water tracing. After two weeks the traces of oil appeared in the springs near Bagnoli (Boljunec) and in the spring of the Osapska Reka (from 0,005 to 0,016 mg/l) while in the Rižana spring the concentration was under 0,005 mg/l (*Knez et al. 1994*). The percolation water was sampled not only in these springs but also in the pools of two caves. The discovery of high oil concentration (the highest being 0,469 mg/l) in this water was most upsetting, although according to the position of the caves and the geological structure it was impossible that the oil, spilled in the above mentioned accident, could penetrate into these caves. Nearby these caves there are another road and double railroad – possible source of oil pollution without any special „ecological accident".

Oil spill by Obrov

In 1994 a similar accident happened in the Slovene part of the Istria peninsula, on the road connecting Trieste with Croatian port of Rijeka, near the village Obrov. 16 m^3 of gas oil flowed off into the karst underground. Rescue workers carried off the soil

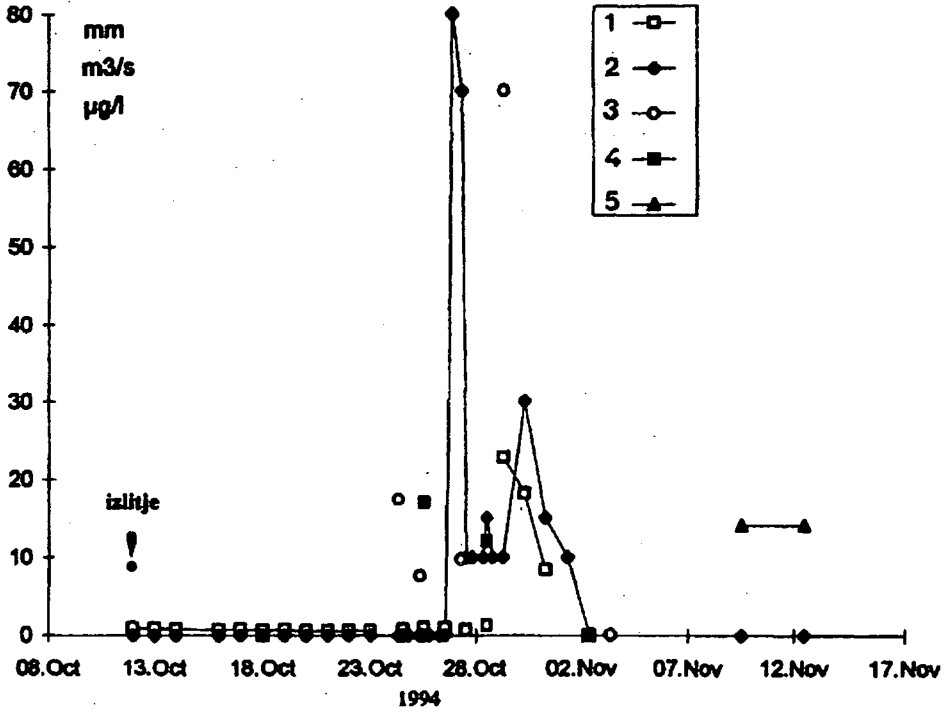

Fig. 5 Pollution concentrations in some karst springs after „Kozina oil spill" (*Kogovšek 1995*).
(1 – mean daily discharge of the Rižana river, 2 – oil concentration in Rižana (µg/l), 3 – rainfall in mm (Podgrad

impregnated by oil, but practically all the oil run away. The region belongs to the 2[nd] protection belt of the captured Rižana river spring, 15,5 km away. The accident point was practically on the contact of Eocene (impermeable) Flysch and intensively karstified limestone. From the sinking point of the nearby stream, flowing down the Flysch Brkini hills, water is flowing underground mainly towards the Rižana springs, and secondary towards Osapska jama cave and spring Ara near Mlini, which was proved by water tracing (*Krivic et al. 1987*) (*Fig. 4*). Oil appeared in the Rižana spring after two weeks. First 12 days after the accident it was dry weather and then heavy rain (70 mm) occurred. The maximum oil concentration was 0,08 mg/l. Based upon the discharge it was reckoned that in 10 days 88 kg of oil run through the springs of Rižana, that means about 0,5 % of all the spill. The oil appeared also in the cave Osapska jama (spring of the Osapska Reka), maximum concentration was 0,014 mg/l, and in the spring Ara near Mlini (maximum concentration 0,017 mg/l) (*Fig. 5*) (*Kogovšek 1995*).

Conclusions

From these examples one can conclude the same, as is already well known among the specialists:

- oil spill on karst can pollute karst springs lying far away also in apparently different morphological, geological or tectonical units;
- oil can remain very long in the karst underground and thus it can pollute water „permanently";
- as a „by-product" of the oil spill detection it was found that karst underground is much more polluted by oil than it was thought, and this is not necessarily the consequence of an identified accident.

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