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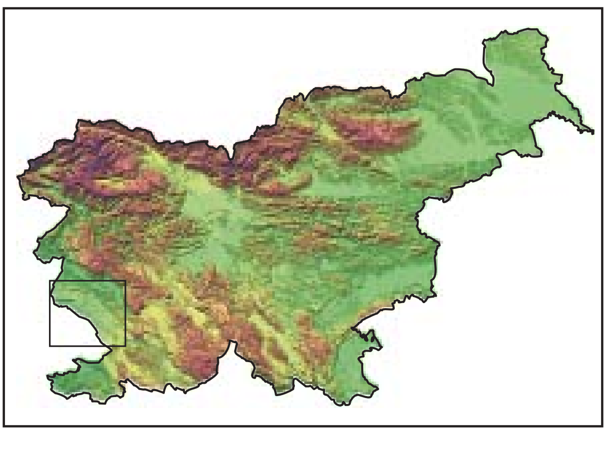
KARST AQUIFER HAZARD ASSESSMENT AND MAPPING ON THE CLASSICAL KARST

OCENJEVANJE IN KARTIRANJE ONESNAŽEVALCEV KRAŠKIH VODONOSNIKOV NA MATIČNEM KRASU

Nataša Ravbar

Drinking water supply on the Kras plateau is mainly based on karst groundwater pumping near Klariči (photograph: Nataša Ravbar).
Oskrba s pitno vodo na Krasu temelji na črpanju kraške podtalnice iz vrtin pri Klaričih (fotografija: Nataša Ravbar).



Karst aquifer hazard assessment and mapping on the Classical Karst

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ABSTRACT: The article presents potential and actual sources of groundwater contamination on the Kras plateau, which is the recharge area of the Klariči karst water source that provides drinking water for the Kras plateau and Koprsko primorje. The water source is insufficiently protected due to inadequate water protection policy and the control over the implementation of the provisions has often been ineffective. Untreated wastewaters, illegal waste-disposal dumps and traffic endanger the water source. The hazards are shown on a simplified map that could be, in a suitable scale, a valuable practical tool for further water source protection and in land-use planning.

KEY WORDS: karst hydrology, karst aquifers, karst groundwater, contamination, hazard assessment and mapping, protection, drinking water, Kras.

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Contents

1 Introduction

Karst aquifers are particularly susceptible to contamination, because of very thin or absent soil, vegetation and/or sediments enabling a rapid flow of the infiltrating water and its distribution over large distances in heterogeneous flow conditions (Ford and Williams 1989, 127–140). For these specific characteristics the overlying layers and concentration of flow enable easy and rapid pathway to the saturated zone. Since there is little opportunity for attenuation of contaminant until it reaches groundwater, spring or well, some serious contamination problems may result from different human impacts.

Karst aquifers are very important for regional and local drinking water supply both in Slovenia and in many other countries of the world. Therefore, human impacts and its effects on karst groundwater studies are becoming more and more important for the proper groundwater protection. The protection of the karst groundwater requires sustainable management, which should be based on comprehensive hazard analyses and karst groundwater vulnerability maps. In the context of groundwater contamination, hazard is defined as an existing and potential source of contamination resulting from human activities taking place mainly at the land surface (De Ketelaere et al. 2004, 86). Hazard assessment and mapping provide a useful conceptual framework within which human activities may be evaluated in holistic terms (Drew and Hötzl 1999, 275).

In order to protect increasingly valuable groundwater resources the concept of hazard mapping is coming to the fore (Špes et al. 2002, 21). For this reason the intensity, extent and duration of an imposed stress need to be quantified. On these basis potential and actual sources of pollution to the groundwater evaluation and maps can be elaborated.

The present article is a study and a review of potential and actual sources of groundwater contamination on the Kras plateau which is the recharge area of a Klariči karst water source near Brestovica, which is close to Kostanjevica na Krasu. Water source provide drinking water for the Kras plateau and the Koprsko primorje region as well (Ravbar 2004, 79–81). Many useful and valuable data were compiled from existing databases and gathered by previous investigations (Kovačič and Ravbar 2005, 226). During the systematic examinations of the studied area in years 2003 and 2004 all potential and actual hazards to groundwater on the Kras plateau were recorded and mapped. In spite of relatively precise survey of the area it is possible that some of the hazards remained unrecorded.

Hazard classification is based on type of human activities. A hazard assessment considers the descriptive information of the existent and potential degree of harmfulness. The most serious potential and actual hazards of groundwater are briefly described below as well as shown on a map. All the mapped hazards were analysed by computer using GIS (ArcView GIS Version 3.1).

2 Some natural characteristics of the Kras plateau

The Karst plateau aquifer belongs to the Low Dinaric karst. It lies in the southwestern Slovenia and covers about 440 km^2. It reaches heights from 200 to 600 metres above the sea level and extends in the northwest-southeast direction. It primarily consists of limestone and dolomite of the Cretaceous and Paleocene age (Kranjc et al. 1999, 25). Along the Vipava valley in the north, the carbonate rock of the Cretaceous age changes into less permeable layers of Tertiary sandstone, plate limestone and flysch, and through Paleocene limestone into Eocene flysch in the south and southwest (Buser 1973; Jurkovšek et al. 1996).

There is no permanent surface water on the Kras plateau. This aquifer is fed by the precipitation and by the sinking rivers at its border: the Reka river, the Sajevški potok stream, the Senožeški potok stream and the streams from the Brkini hills (Krivic et al. 1989). In the northwest the aquifer is also fed by underground infiltration of the intergranular aquifer of the Vipava and Soča rivers (Figure 1). The Kras aquifer empties in numerous small superficial and submarine karst springs on the western and northwestern edge. We can deduce that the groundwater level is inclined from southeast to northwest and from east to west (Habič 1984, 62).

According to the Cadastre of Caves (2003), 626 caves, among which shafts prevail, were registered in the studied area. The density of their entrances is among the highest in Slovenia. It reaches from 1.5 up to 2.4 entrances per km^2. In spite of very high density the majority of underground water channels is not

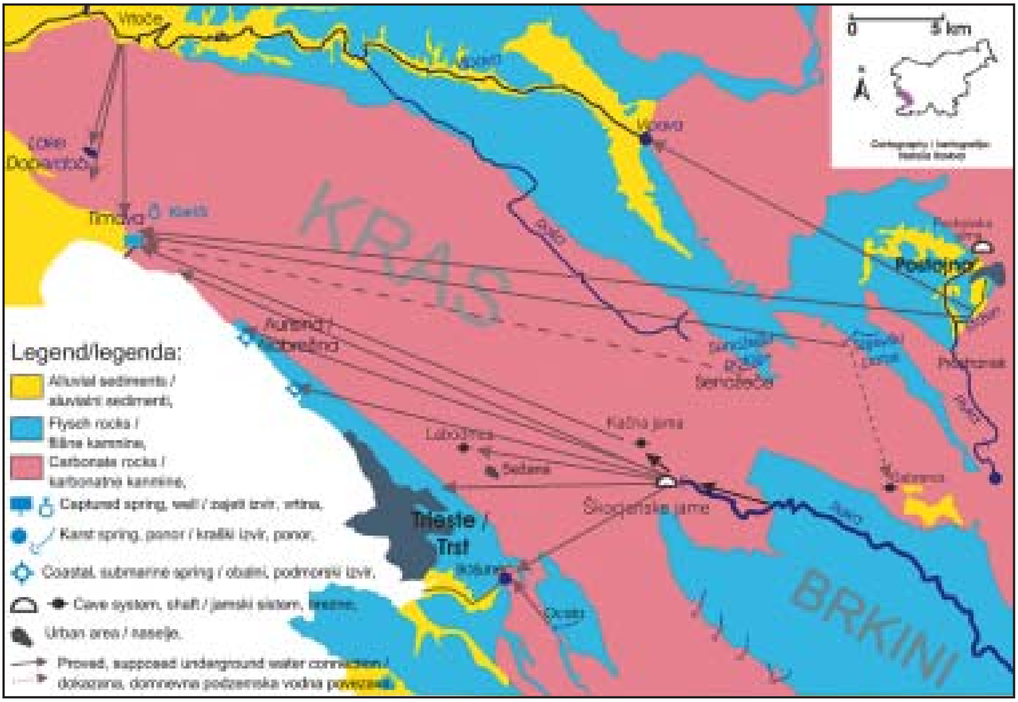

Figure 1: Simplified geological map of the Kras plateau with proved and supposed groundwater connections (Cività s sodelavci 1995; Buser et al. 1963; Buser 1964; Gemiti 1984; Pleničar et al. 1965; Timeus 1928).

accessible. One can only reach permanent or periodical water flow in seven caves. Therefore information on underground water circulation is very limited.

The aquifer of the Kras plateau is an important source of drinking water; the advantages of its capacities are not yet fully taken (Krivic 1983). Water supply is based on the effective karst groundwater pumping near Klariči, providing a yearly yield of about two millions m^3 of water and supplying more than 22,500 people (Ravbar 2004, 79–81). The water source is sufficient enough to supply the Koprsko primorje region during the summer tourist season as well.

3 Description of hazards

3.1 Settlements

The most frequent sources of pollution of karst groundwater result from household sewages, polluted waters from roads and traffic, industrial polluted wastewaters and illegal dumps. Potential polluters are also oil reservoirs that have been built unprofessionally and without control.

The Kras plateau is relatively disperse and scarcely inhabited (Figure 2) – the density of population is 44 inhabitants per km^2 (Internet 4). From 1961 to 1991 the growth of inhabitants has been very modest, only 9,5% (Perko and Orožen Adamič 1998, 234).

There are clumpy little villages with up to 200 inhabitants and five settlements (Sežana, Divača, Dutovlje, Komen and Lokev) with more than 500 inhabitants. Urban way of life predominates in municipal centers. The largest settlement is Sežana (4800 inhabitants), which is also the industrial, administrative and cultural centre of Kras. Divača (1300 inhabitants) is an important railway junction.

Sewage systems in the settlements of the studied area are very limited. All settlements on the plateau except Sežana, Divača and Senožeče still do not have regulated sewerage and treatment of sewage. In the

Figure 2: Štanjel is an example of a clumpy settlement (photograph: Nataša Ravbar).

town of Sežana only 55% of waste and of public utility water is drawn off purifying plant. About 440 cesspits are still in use. Additionally in town of Senožeče 70% of waste and of public utility waters is drawn off purifying plant, while in Divača only 35%. Wastewater from households in other settlements is drawn off to cesspits and there is only a small portion of such that have impermeable bottoms.

3.2 Waste material disposal

One of the biggest polluters of karst groundwater on the Kras plateau is landfill of waste materials near Sežana. It is intended for disposal of waste materials from households and of special waste materials from industry, and of craft and other activities under conditions, which are paraphrased by the Rules on the management of waste (Ur. l. SRS št. 20/86). The landfill of waste materials in Sežana has legally regulated status, but it does not entirely meet the demands of the new Slovene legislation (Internet 1) and European guidelines (Council Directive 1999/31/EC).

Analyses of discharge waters from the Sežana dump have shown high organic pollution. COD and BOD_5 have exceeded the limit value for several times. Evaluations of the tracing tests have shown, that discharge waters from the Sežana dump can reach sources of the Timavo river within three to twelve days (Kogovšek 1996, 113). The existing dump is already old and urgently needs rebuilding and widening. An enlargement of the dump place to the west and to the northwest for additional 5 ha is foreseen.

Numerous illegal garbage dumps on the karst terrain may also influence the quality of groundwater by bacterial and chemical load. On the Kras plateau landfills of local origin are the most frequent. In 2003 there have been 59 illegal dumps registered on the surface of the studied area and another 55 of them in the caves (Figure 3).

Illegal garbage dumps derive from times when collection of waste was not organized. Many of them are, unfortunately, still in use today. Among waste material building and excavation material, rural and furniture waste material prevail. There are also dangerous materials (refrigerators, motor vehicles, accumulators, battery, varnishes and motor oils, packaging of cleaning means, remainders of agrochemical

Figure 3: Landfill of waste materials near Sežana (photograph: Nataša Ravbar).

means, dismissed chemical and computer equipment). On such dumps one can often find old ironware, isolative material, pneumatic tires, waste from gardens or fields and other.

In spite of restrictions and interdiction of definite activities on the protected area we found that in the second water protection zone of the Klariči water source there is an abandoned illegal dump of building material. In the third water protection zone, where spreading of certain activities is strictly forbidden we identified twelve more illegal dumps that mostly consisted of rural, building and also of dangerous waste materials. In two additional cases we recorded dumps in a direct vicinity of a stream that on the border area of the studied area sinks into the underground.

Among the known caves more than eight percent of them are polluted. There are mainly waste of public utility origin, dead animal bodies and slaughter waste material, furniture and military ammunition. Analyses of discharged waters in selected caves that have been done by the Sežana speleologists (Sanacija onesnaženih jam 1998) have shown too high values of insoluble and sedimented substances, COD and BOD_5 (Ur. l. RS št. 35/96). Concentrations of noxious matter, heavy metals and mineral oils, which were washed directly into the aquifer, were extremely high.

It is also necessary to emphasize, that these caves are inside the water protection zones of the Klariči water source or in the vicinity of a supposed underground water flow of the Reka river. Therefore contamination of this type of point pollution is by no means negligible.

3.3 Traffic

The Kras plateau lies on the crossroads of important routes, which connect Northern Adriatic Sea with Panonian basin respectively linking the Mediterranean and Central Europe. On the Kras plateau traffic has a traditional meaning and plays an important role in economy of this area.

The most burdened are highway sections, which mostly have transit role and traverse southern part of the studied area. Average daily traffic on highways reached 12,812 vehicles in 2001. An average of 15,000 vehicles daily was measured on the most traffic section Razdrto–Senožeče, which also represents a bottleneck before the northern part leading towards Trieste splits the southern one that leads towards Koper (Promet 2001; 2002). Average part of freight traffic through highways and regional roads is 13% (Figure 4).

Figure 4: The Kras plateau lies on the crossroads of important traffic routes (photograph: Nataša Ravbar).

Only the highway sections and the main road in Sežana have regulated roadside channels, where meteoric waters are collected and drained off. Dirt is washed directly underground from the other roadways. Therefore transport of dangerous material signifies a special danger in freight traffic. Accidents could cause uncontrolled leakage into environment. Another potential sources of karst groundwater burdening are petrol services. In 2003 there were eight gasoline services operating on the Kras plateau. All, except two of them, have been improperly built and did not have regulated drainage of wastewater through oil filters.

Due to mild climate salting of roads on the plateau is not intensive, but yet has a certain effect on the karst groundwater. For strewing usually sodium's chloride with additions and calcium's dichloride solution is used. Often also heavy metal or mercury is added. Annual amount of salt that is spent for strewing of state and local roads on the Kras plateau amounts to around 740 tons. Important contamination of groundwater because of salting has not been yet discovered.

Over the studied area around 70 kilometres of railway tracks run. In 2002 altogether 28,105 passenger trains drove. That is 40 percent of all transports across the Kras plateau (Internet 3). Slovenian Railways estimate, that over nine millions tons of goods have been carried over border crossings Fernetiči and Vrtojba and Port of Koper in 2002. Six percent were chemical products and nine percent petroleum and derivatives. The most dangerous materials have been carried over the section Ljubljana–Koper that crosses Kras. Although transport of dangerous material by railway is safer than transport by road, the biggest part of transportation is still based on road transport.

3.4 Agriculture

Natural circumstances of the Kras plateau are not the most convenient for agriculture. In spite of traditional economic activity based upon wild pear breeding and agronomy, region represented supplying hinterland of Trieste. Agriculture is no longer an important activity and is restricted to cultivation of small fields on the bottom of depressions on the plateau.

But viticulture is coming to the fore and is becoming the most profitable rural activity recently. Vineyards cover only three percent of land, mostly in the vicinity of Dutovlje, Tomaj, Križ, Avber, Komen, Kobdilj and Utovlje. In the municipalities of Komen and Sežana area of vineyards commonly exceeds 450 ha. In the vicinity of Tomaj and Dutovlje the production of fruit is enforced as well (Internet 2, Vrišer 2002).

Intensely cultivated vineyards and orchards, where a lot of fertilizers and protective means are used, are the areas most exposed to suspended pollution. Because in intensive viticulture the quantity and quality of the crops depend completely on use of the phyto-pharmaceutical products, for achieving bigger yields winegrowers usually use too much of these preparations (Rejec Brancelj 2001).

On the Kras plateau constant sources of pollution are also disorderly-manured dung heaps, cesspits and stocks of stable manure, from where discharge waters drain directly underground. Diffuse sources of pollution are immoderate fertilizing of fodder plants, above all with mineral fertilizers, use of other agrochemical means for protection of plants and uncontrolled fertilizing with manure during the wrong time of the year.

Stockbreeding in the studied area is negligible. There are no bigger cattle or pork farms. However, cooperative breeders of poultry prevail. They breed 20,000–80,000 animals per year. Settlements exceeding 0,5 LU/ha (livestock units per hectare) are very rare: Volčji grad, Lipa, Vojščica, Brestovica pri Povirju, Kazlje, Opatje selo, Lokev and Utovlje. Settlements that exceed 0,8 LU/ha are Voglje, Štorje and Sveto (Internet 4).

The stud farm and tourist recreational centre Lipica is the biggest supposed polluter of the karst groundwater. It contaminates groundwater with disorderly discharges of dirty water from the stables and with sewage. It consumes 70,500 m^3 of water yearly. Wastewaters are drawn off to obsolete and too small water treatment plant with mechanical treatment, and then directly into environment. The analyses of the outflow (Poročilo o obratovalnem monitoringu odpadnih voda 2002) showed that this source of pollution immoderately contaminates the environment. Measured values of COD, BOD_5, total phosphorus, suspended solids, nitrites and total tenzides surpassed the maximum permissible values (Ur. l. RS 35/96).

3.5 Industry

Industrial development started only after the Second World War, especially in Sežana, Divača and Komen. But only few factories have survived economical recession in the 1990s. Therefore industrial pollution, which has achieved the highest point in the eighties, is considerably reduced. Improvement of sanitary conditions that numerous factories have accepted also helped to the reduction of the environmental pollution by industrial sewages.

Today the industrial production on the Kras plateau is limited and concentrated above all in bigger urban areas. Most important industrial city is Sežana, where food, textile, chemical and construction industry and continental terminal are located. In Divača there are a factory of electric machines and some other smaller industrial plants. In Komen there is a construction industry, in Dutovlje wood industry and in Šepulje a meat processing industry. Industrial effluents are also a source of groundwater contamination if wastewater collection and drainage systems are not built or are not efficient.

Concerning industries the biggest pollutant of karst groundwater is the ham-curing plant Kras at Šepulje, one of the leading meat processing industries in Slovenia. Annual amount of consumed water reaches 46,570 m^3. Since they do not have their own water treatment plant built they draw off the technical waters and sewage directly into the nature. The analyses of discharge waters have shown, that they contain too big toxicity for water fleas and too high values of oil and grease, total phosphorus, chloride, COD and BOD_5 (Poročilo o vzorčenju odpadne vode in terenskih meritvah 2001).

Mitol, the glue factory in Sežana, is a very big consumer of water and producer of technological sewage on the Kras plateau. Annually they spend 17,300 m^3 of water for raw material, cooling and elution of receptacles and other equipment. They have their own wastewater treatment plant and regulated wastewater treatment. Their technological sewage is at first drawn off their own water treatment plant and then to the public water treatment plant, where they do not exceed stipulated values (Poročilo o vzorčenju odpadne vode in terenskih meritvah 2002). But at the same time it is also one of the biggest potential polluters of karst groundwater because of possibility of pouring out of chemical substances. They store 250–300 t of dangerous material, which is kept in entrenched reservoirs.

3.6 Tourism

Tourist potential of the Kras plateau is extraordinarily high. However, its offer and service is still very moderate. The area has big possibilities for development of different ways of tourism, because it lies in the hinterland of important coastal towns (Koper, Trieste, Monfalcone). Arrangement of dispersed tourist centers would be reasonable in order to make drinking water sources of the Kras plateau exposed to human impacts due to tourism as small as possible. For that it would be necessary to consider carefully, what degree of tourist visit the plateau can accept in sense of increased consumption of drinking water and the consequent enlarged amounts of wastewaters, big hotel and other accommodation constructions, parking facilities and increased traffic.

4 Conclusion

The response of the karst environment and its constituents on the anthropogenic pollution is very specific and characteristically differs from other environments. Transport of the contaminants through the unsaturated zone, where substances can retain underground from few minutes to several years, is very complex. Unpredictable is also traveling of the contaminants through the saturated zone, because the conditions of the main karst channels are usually unknown (Ford and Williams 1989, 518–521).

Therefore we can very hardly forecast the consequences of different anthropogenic activities to the karst environment. However, direct outflow of the discharge waters into the karst aquifer without preliminary cleaning could slowly but persistently poison stock of drinking water. In case of outflow of dangerous substances karst water resource could be permanently poisoned as an example of the Krupa spring in the Bela Krajina region, SE Slovenia (Polič et al. 1999). For this reasons it is necessary to devote our attention to the influences of human impacts on behaviour of karst waters and to prevent or reduce these negative impacts.

Hazard and vulnerability maps are essential tools for national and local entities with relevant responsibilities at the planning and decision making level. Even though methodology for making these maps in Slovenia is not enacted yet some studies at different areas have already been made (Janža and Prestor 2002; Petrič 2002).

Present study shows that diverse types of hazards, coming from different human activities, threaten the groundwater of the Kras plateau. A hazard assessment and mapping of the Kras plateau considers the existent and potential degree of harmfulness for each type of hazard. Prevailing source of pollution of karst groundwater comes from settlements without wastewater treatment. Several domestic houses have built-in cesspits, which are not properly constructed. Settlements contaminate groundwater mainly because of untreated faecal and domestic wastewaters, a growing consumption of chemical cleaning agents and detergents as well. In the vicinity of many of the settlements illegal waste-disposal dumps appear. They may influence the quality of groundwater by bacterial and chemical load.

Traffic that is crossing the recharge area is a serious potential source of accidental contamination. Sources of contamination are also industrial effluents, specially in the cases, where wastewater collection and drainage systems are not built. An example is the ham-curing plant. Agriculture and farming are not intensive on the Kras plateau, therefore they do not significantly affect the quality of the karst groundwater, except in the case of viticulture, where the influence of the extensive usage of fertilizers and protective means on the quality of karst groundwater is not negligible (Figure 5).

The conditions for groundwater protection are not very favourable on the Kras plateau that is relatively densely inhabited (in comparison to High Dinaric Karst and Alpine Karst) and threatened by diverse types of hazards. Additional reasons are inadequate consideration of special characteristics of water flow in karst and very high karst water sources vulnerability, disorder in water protection, conflicting interests in land use and the lack of knowledge about sustainable water management.

Since monitoring points of groundwater pollution are very scarce in karst hydrological systems due to their heterogeneity, the detection of actual hazards is very difficult. So chemical and bacteriological analyses performed at springs and wells are another possibility of detecting eventual contamination. Although extensive exploration of karst aquifers has often been avoided until now, some signs of contamination have already been recorded in several karst springs in Slovenia (Kovačič and Ravbar 2005, 232). Negative impacts to karst groundwater on the Kras plateau are shown in the drinking water analyses, such as increased presence of *coliform* bacteria and bacteria *Escherichia coli*. These bacteria are indicators of fresh

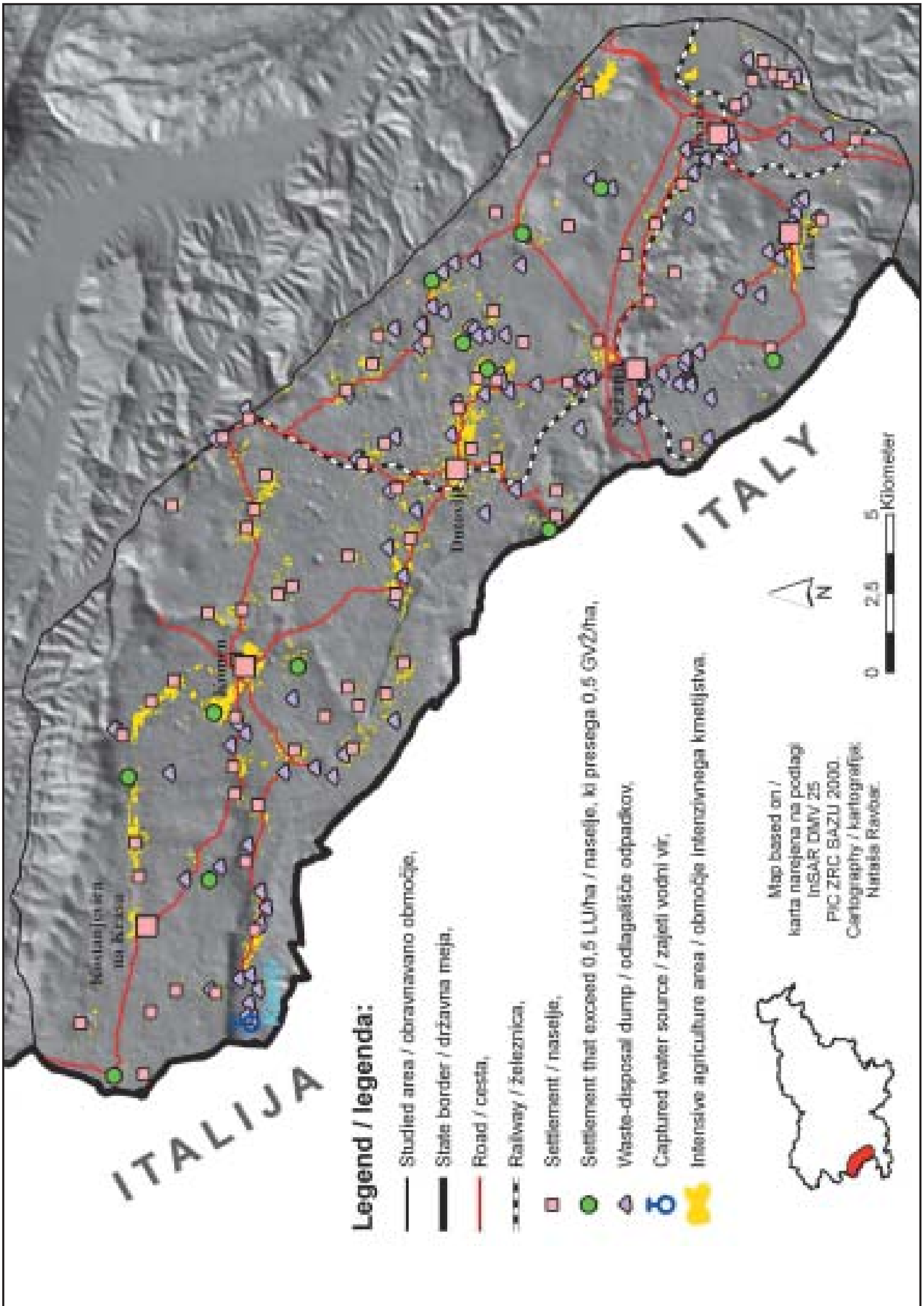

Figure 5: Hazards to karst groundwater on the Kras plateau.

contamination with fecal wastewater. However, the concentrations did not exceed the maximum permissible values for drinking water.

In order to preserve quality quantities of karst groundwater for exploitation in the future, it is necessary to establish an adequate protection. Adequate elaborated vulnerability map of karst water sources based on actual and potential mapping are essential. Therefore hazard mapping is a valuable practical tool for further water sources protection and land-use planning.

5 References

Buser, S. 1964: Osnovna geološka karta SFRJ 1 : 100.000, list Gorica. Savezni geološki zavod. Beograd.

Buser, S. 1973: Osnovna geološka karta SFRJ 1 : 100.000, Tolmač lista Gorica. Savezni geološki zavod. Beograd.

Buser, S., Grad, K., Pleničar, M. 1963: Osnovna geološka karta SFRJ 1 : 100.000, list Postojna. Savezni geološki zavod. Beograd.

Cività, M., Cucchi, F., Eusebio, A., Garavoglia, S., Maranzana, F., Vigna, B. 1995: The Timavo Hydrogeologic system, An important reservoir of supplementary water resources to be reclaimed and protected. Acta Carsologica 24, 169–186. Ljubljana.

Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Uradni list RS 182.

De Ketelaere, D., Hötzl, H., Neukum C., Cività, M., Sappa, G. 2004: Hazard Analysis and Mapping. In: Vulnerability and Risk Mapping for the Protection of Carbonate (Karstic) Aquifers. Final report COST Action 620. Brüssel.

Drew, D., Hötzl, H. 1999: Karst Hydrology and Human Activities. International Contributions to Hydrogeology. Rotterdam.

Ford, D. C., Williams, P. W. 1989: Karst geomorphology and hydrology. Unwin Hyman Ltd. London.

Gemiti, F. 1984: La portata del Timavo alle risorgive di S. Giovanni di Duino. Annali Gruppo Grotte Ass. XXX Ott. 7. Trieste.

Habič, P. 1984: Vodna gladina v Notranjskem in Primorskem krasu. Acta Carsologica 13, 37–78. Ljubljana.

Janža, M., Prestor, J. 2002: Ocena naravne ranljivosti vodonosnika v zaledju izvira Rižane po metodi SINTACS. Geologija 45, 2, 401–406, Ljubljana.

Jurkovšek, B., Toman, M., Ogorelec, B., Šribar, L., Drobne, K., Poljak, M., Šribar., L. 1996: Formacijska geološka karta južnega dela Tržaško-Komenske planote, Kredne in paleogenske karbonatne kamnine. Inštitut za geologijo, geotehniko in geofiziko. Ljubljana.

Kataster jam 2003. Jamarska zveza Slovenije, Inštitut za raziskovanje krasa ZRC SAZU. Postojna.

Kogovšek, J. 1996: Kako smetišča ogrožajo kakovost kraške vode. Annales 9, 111–114. Koper.

Kovačič, G., Ravbar, N. 2005: A review of the potential and actual sources of pollution to groundwater in selected karst areas in Slovenia. Natural Hazards and Earth Systems Science 5, 225–233. Berlin.

Kranjc, A. 1999. Kras, Pokrajina, življenje, ljudje. Založba ZRC, ZRC SAZU. Ljubljana.

Krivic, P. 1983: Interprétation des essais par pompage réalisés dans un aquifère karstique. Geologija 26, 149–186. Ljubljana.

Krivic, P., Bricelj, M., Zupan, M. 1989: Podzemne vodne zveze na področju Čičarije in osrednjega dela Istre (Slovenija, Hrvatska, NW Jugoslavija). Acta Carsologica 18, 265–295. Ljubljana.

Internet 1: http://objave.uradni-list.si/ (2. 4. 2003).

Internet 2: http://www.sigov.si/zrs/kmet00/kmet.htm (18. 3. 2003).

Internet 3: http://www.slo-zeleznice.si/ (7. 1. 2003).

Internet 4: http://www.stat.si/popis2002/si/default.htm (17. 4. 2003).

Perko, D., Orožen Adamič, M. 1998: Slovenija, Pokrajine in ljudje. Mladinska knjiga. Ljubljana.

Petrič, M. 2002: Strokovne podlage za varovanje lokalnih vodnih virov na območju občine Postojna. Znanstvenoraziskovalni center SAZU, Inštitut za raziskovanje krasa, Postojna.

Pleničar, M., Polšak, A., Šikić, D. 1965: Osnovna geološka karta SFRJ 1 : 100.000, list Trst. Savezni geološki zavod. Beograd.

Polič, S., Leskovšek, H., Horvat, M. 1999: PCB pollution of the Karstic Environment (Krupa River, Slovenia). Acta Carsologica 29, 141–152. Ljubljana.

Poročilo o obratovalnem monitoringu odpadnih voda za leto 2002. Kobilarna Lipica. 2002. Zavod za zdravstveno varstvo Koper, Oddelek za higieno. Koper.

Poročilo o vzorčenju odpadne vode in terenskih meritvah. Mitol. 2002. Zavod za zdravstveno varstvo Koper, Oddelek za higieno. Koper.
Poročilo o vzorčenju odpadne vode in terenskih meritvah. Pršutarna Šepulje. 2001. Zavod za zdravstveno varstvo Koper, Oddelek za higieno. Koper.
pravilnik o ravnanju s posebnimi odpadki, ki vsebujejo nevarne snovi. 1986. Uradni list SRS 20.
Promet 2001, Podatki o štetju prometa na državnih cestah v Republiki Sloveniji. 2002. Direkcija Republike Slovenije za ceste. Ljubljana.
Ravbar, N. 2004: Drinking water supply from karst water resources, The example of Kras plateau, SW Slovenia. Acta Carsologica 33, 1, 73–84. Ljubljana.
Rejec Brancelj, I. 2001: Kmetijsko obremenjevanje okolja v Sloveniji. Pokrajinski vidiki obremenjevanja iz razpršenih virov. Inštitut za geografijo. Ljubljana.
Sanacija onesnaženih jam. 1998, Jamarsko društvo Sežana. Phare program prekomejnega sodelovanja. Sežana.
Špes, M., Cigale, D., Lampič, B., Natek, K., Plut, D., Smrekar, A. 2002: Študija ranljivosti okolja. Metodologija in aplikacija. Geographica Slovenica 35, 1–2, 1–150. Ljubljana.
Timeus, G. 1928: Nei misteri delmondo sotterraneo, Risultati delle ricerche idrologiche sul Timavo 1895–1914, 1918–1927. Alpi Giulie 19, 1–39. Trieste.
Uredba o emisiji snovi in toplote pri odvajanju odpadnih voda iz virov onesnaževanja. 1996. Uradni list RS 35.
Vrišer, I. 2002: Agricultural production in the Republic of Slovenia (According to the Census of the Agricultural Sector 2000). Acta Geographica Slovenica 42, 8–60. Ljubljana.

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IZVLEČEK: Prispevek obravnava potencialne in dejanske vire onesnaževanja vodnega vira Klariči, ki s pitno vodo oskrbuje prebivalce Krasa in Koprskega primorja. Vodni vir je zaradi pomanjkljive vodovarstvene politike neustrezno zavarovan, nadzor nad kršitelji določil pa pogosto neučinkovit. Ogrožajo ga neprečiščene odpadne vode, divja odlagališča odpadkov in promet. Onesnaževalci so prikazani na poenostavljeni karti, ki je v ustreznem merilu lahko koristna osnova za nadaljnje načrtovanje varovanja vodnih virov in rabe prostora.

KLJUČNE BESEDE: kraška hidrologija, kraški vodonosniki, kraška podtalnica, onesnaževanje, ocenjevanje in kartiranje onesnaževalcev, pitna voda, Kras.

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Kazalo

1 Uvod

Kraški vodonosniki so izredno občutljivi na onesnaženje zaradi tanke ali odsotne zaščitne plasti prsti in rastja ter sedimentov, pa tudi zaradi velikih hitrosti pretakanja voda, hitrega prenosa snovi daleč stran od vira ter heterogenega pretakanja voda v podzemlju (Ford in Williams 1989, 127–140). Te specifične lastnosti kraških vodonosnikov (prekrivajoči sloji, koncentracija toka) omogočajo lahek in hiter odtok vode do zasičene cone. Ker so možnosti razgradnje onesnaževal na poti do podzemne vode, zajetega kraškega izvira ali vodnjaka majhne, lahko različni človeški vplivi povzročijo močno onesnaženje vodnih virov.

Kraški vodonosniki so na krajevni in regionalni ravni izredno pomembni za oskrbo z vodo. Prav zato so za ustrezno varovanje podzemne vode vedno pomembnejše tudi študije človekovih vplivov na kraško podtalnico in njihovih posledic. Zaščita kraške podtalnice zahteva trajnostno gospodarjenje, ki naj bi temeljilo na obsežnih analizah onesnaževalcev in na kartiranju ranljivosti kraške podtalnice. Onesnaževalec je obstoječi ali potencialni vir onesnaženja, izhajajoč iz določenih antropogenih aktivnosti, ki navadno potekajo na površju (De Ketelaere s sod. 2004, 86). Ocenjevanje in kartiranje onesnaževalcev je koristna osnova, v okviru katere so človekove aktivnosti celovito ovrednotene (Drew in Hötzl 1999, 275).

Da bi zaščitili vse bolj dragocene zaloge podtalnice se uveljavlja koncept kartiranja onesnaževalcev (Špes s sod. 2002, 21). Zato pa je potrebno določiti intenzivnost, obseg in trajanje določenega onesnaževanja. Na tej osnovi izdelamo oceno ter zemljevide potencialnih in dejanskih virov onesnaževanja podtalnice.

Prispevek obravnava potencialne in dejanske vire onesnaževanja podtalnice v zaledju vodnega vira Klariči pri Brestovici v bližini Kostanjevice na Krasu, ki s pitno vodo oskrbuje prebivalce Krasa in Koprskega primorja (Ravbar 2004, 79–81). Nekaj uporabnih in koristnih podatkov je bilo pridobljenih na podlagi obstoječih podatkovnih baz ali so bili zbrani v predhodnih raziskavah (Kovačič in Ravbar 2005). V letih 2003 in 2004 so bili popisani in locirani vsi potencialni ter dejanski onesnaževalci podtalnice na Krasu. Kljub razmeroma natančnemu pregledovanju terena dopuščamo možnost, da je kateri od onesnaževalcev ostal nezabeležen.

Onesnaževalce smo razvrstili glede na vrsto človekovih dejavnosti, njihova ocena pa temelji na opisnih informacijah obstoječe in potencialne stopnje škodljivosti. Najnevarnejši potencialni in dejanski onesnaževalci podtalnice na Krasu so na kratko opisani in prikazani na zemljevidu, ki je bil izdelan s pomočjo orodij GIS (*ArcView*, različica 3.1).

2 Nekatere naravnogeografske značilnosti Krasa

Nizka kraška planota Kras leži v jugozahodni Sloveniji in zavzema površino okoli 440 km^2. Razprostira se v smeri od severozahoda proti jugovzhodu in v višinah 200–600 m. Gradijo ga predvsem apnenci in dolomiti kredne in paleocenske starosti (Kranjc s sod. 1999, 25). Ob Vipavski dolini na severu prehajajo karbonatne kamnine kredne starosti v manj prepustne plasti terciarnega lapornatega in ploščastega apnenca ter fliša, na jugu in jugozahodu pa prek paleocenskega apnenca v eocenski fliš (Buser 1973; Jurkovšek s sod. 1996).

Na Krasu ni površinskih tekočih voda. Kraški vodonosnik napajajo padavine in ponikalnice, ki pritekajo z nekraškega obrobja: Reka, Sajevški potok, Senožeški potok in potoki z Brkinov (Krivic s sod. 1989), na severozahodnem obrobju pa podzemna voda iz soškega in vipavskega medzrnskega vodonosnika (slika 1). Kraški vodonosnik se prazni na jugozahodni in zahodni strani v obliki številnih obalnih in podmorskih izvirov. Sklepamo lahko, da je gladina podtalnice v Krasu nagnjena od jugovzhoda proti severozahodu in od vzhoda proti zahodu (Habič 1984, 62).

Po podatkih Katastra jam (2003) je bilo na obravnavanem območju registriranih 626 kraških votlin, med katerimi prevladujejo brezna. Čeprav je gostota jamskih vhodov na Krasu med največjimi v Sloveniji, in dosega 1,5 do 2,5 jamskih vhodov na km^2, je podzemska voda le redko dostopna, zato so informacije o pretakanju vode v podzemlju zelo omejene. Stalni ali občasni vodni tok lahko opazujemo le v sedmih kraških jamah.

Vodonosnik Krasa je pomemben zaradi zalog pitne vode, saj njegove vodne kapacitete še zdaleč niso povsem izkoriščene (Krivic 1983). V Klaričih letno načrpajo okoli dva milijona m^3 vode in oskrbujejo več kot 22.500 prebivalcev (Ravbar 2004, 79–81), v poletnih mesecih pa z vodo oskrbujejo še Koprsko primorje.

Slika 1: Poenostavljena geološka karta Krasa z dokazanimi in domnevnimi vodnimi zvezami (Cività s sodelavci 1995; Buser s sodelavci 1963; Buser 1964; Gemiti 1984; Pleničar s sodelavci 1965; Timeus 1928).
Glej angleški del prispevka.

3 Opis onesnaževalcev

3.1 Naselja

Najpogostejši viri onesnaževanja kraške podtalnice na Krasu so odplake, izcedne vode s cest, industrije, divjih odlagališč odpadkov in drugod. Možni onesnaževalci so tudi nestrokovno in brez nadzora vgrajeni rezervoarji za kurilno olje.

Kras je sorazmerno redko poseljen (slika 2), gostota poselitve je 44 prebivalcev na km^2 (Internet 4). Od leta 1961 do leta 1991 je bila rast števila prebivalcev skromna, le 9,5-odstotna (Perko in Orožen Adamič 1998, 234).

Slika 2: Štanjel je primer gručastega naselja (fotografija: Nataša Ravbar).
Glej angleški del prispevka.

Na krasu prevladujejo gručasta naselja z manj kot dvesto prebivalci. Le pet jih šteje več kot 500 prebivalcev: Sežana, Divača, Dutovlje, Komen in Lokev. Urban način življenja prevladuje predvsem v večjih naseljih. Največje naselje Sežana (4800 prebivalcev) je upravno in kulturno središče ter sedež različnih industrijskih dejavnosti. Divača (1300 prebivalcev) je pomembno železniško vozlišče.

Kanalizacijsko omrežje v naseljih obravnavanega območja je skromno. Številna naselja na Krasu, z izjemo Sežane, Divače in Senožeč, še vedno nimajo urejene kanalizacije ter čiščenja odpadnih voda. V Sežani še vedno uporabljajo 440 greznic, zato le 55 % odpadnih in komunalnih voda odvajajo prek kanalizacije v čistilno napravo. V Senožečah v čistilno napravo odvajajo 70 % odpadnih in komunalnih voda, v Divači pa le 35 %. V ostalih naseljih so odpadne vode iz gospodinjstev speljane v greznice ali gnojne jame. Le majhen delež je takšnih, ki imajo nepropustno dno.

3.2 Odlagališča odpadkov

Odlagališče odpadkov v Sežani je eden največjih onesnaževalcev kraške podtalnice. Namenjeno je odlaganju odpadkov iz gospodinjstev in posebnih odpadkov iz industrije, obrti ter drugih dejavnosti. Odpadke odlagajo pod pogoji, določenimi v pravilniku o ravnanju s posebnimi odpadki, ki vsebujejo nevarne snovi (Ur. l. SRS št. 20/86). Odlagališče sicer ima zakonsko urejen status, vendar ne ustreza v celoti zahtevam nove slovenske zakonodaje (Medmrežje 1) in Evropskim smernicam (Council Directive 1999/31/EC).

Izcedne vode sežanskega odlagališča odpadkov so pogosto organsko onesnažene. KPK in BPK_5 sta večkrat presegli mejno vrednost. Sledenja so pokazala, da lahko izcedne vode iz sežanskega smetišča dosežejo izvire Timava že v času treh do dvanajstih dni (Kogovšek 1996, 113). Obstoječe odlagališče odpadkov je že staro ter nujno potrebno sanacije. Predvidena je bila širitev deponijskega prostora proti zahodu in severozahodu za dodatnih 5 ha.

Na kakovost podtalnice lahko vplivajo tudi številna divja odlagališča odpadkov. Najpogostejša so odlagališča lokalnega izvora. Leta 2003 smo popisali 59 divjih odlagališč odpadkov na površju in 55 divjih odlagališč v jamah in breznih (slika 3). Te jame so v varstvenem pasu vodnega zajetja Klariči ali v neposredni bližini podzemskega toka Reke. Zato vsako točkovno onesnaženje nikakor ni zanemarljivo.

Slika 3: Odlagališče odpadkov v Sežani (fotografija: Nataša Ravbar).
Glej angleški del prispevka.

Divja odlagališča izvirajo iz časov, ko odvoz odpadkov še ni bil organiziran. Mnoga med njimi še danes uporabljajo. Med odpadki prevladujejo gradbeni in izkopni material, kmetijski in kosovni odpadki, med katerimi so tudi nevarni (na primer hladilniki, motorna vozila, akumulatorji, baterije, laki, motorna olja, embalaža čistilnih sredstev, ostanki agrokemičnih sredstev, kemikalije in računalniška oprema). Zelo pogosto na tovrstnih odlagališčih najdemo še staro železje, izolacijski material, pnevmatike, odpadke z vrtov ali njiv in drugo.

Kljub omejitvam in prepovedim na območju varstvenih pasov smo na območju drugega varstvenega pasu vodnega vira Klariči evidentirali opuščeno odlagališče gradbenega materiala. Na območju tretjega varstvenega pasu, kjer je širjenje določenih dejavnosti omejeno, smo popisali dvanajst divjih odlagališč pretežno kmetijskih, gradbenih in tudi nevarnih kosovnih odpadkov.

Na obravnavanem območju je onesnaženih osem odstotkov vseh znanih kraških jam. Prevladujejo komunalni odpadki, klavniški odpadki, kosovni odpadki ter vojaško strelivo. Analize izcednih voda v izbranih jamah, ki so jih opravili sežanski jamarji (Sanacija onesnaženih jam 1998), so pokazale previsoke vrednosti neraztopljenih in usedljivih snovi ter KPK in BPK_5 (Ur. l. RS št. 35/96). Koncentracije škodljivih snovi, težkih kovin in mineralnih olj, ki so se spirale neposredno v vodonosnik, so bile izjemno visoke.

3.3 Promet

Kras leži na križišču pomembnih poti, ki povezujejo severni Jadran s Panonsko kotlino oziroma severno Sredozemlje s srednjo Evropo. Promet ima na Krasu tradicionalno vlogo in je pomemben v gospodarstvu tega ozemlja.

Prometno so najbolj obremenjeni avtocestni odseki, ki imajo večinoma tranzitno vlogo in prečkajo južni del matičnega Krasa. Povprečni dnevni promet na avtocestah po Krasu je leta 2001 dosegel 12.812 vozil. S povprečno 15.000 vozili dnevno je bil najbolj prometen odsek Razdrto–Senožeče, ki je ozko grlo med razcepom severnega kraka proti Trstu in južnega proti Kopru (Promet 2001; 2002). Trinajst odstotkov prometa, ki poteka po avtocestah in regionalnih cestah, je tovornega (slika 4).

Slika 4: Kras leži na križišču pomembnih prometnih poti (fotografija: Nataša Ravbar).
Glej angleški del prispevka.

Na Krasu imajo le avtocestni odseki in glavna cesta v Sežani urejene obcestne kanale, kjer se meteorna voda zbira in odteka v meteorni kanalizacijski sistem. Z vseh ostalih cestišč se umazanija spira neposredno v podzemlje. Posebno so nevarni prevozi nevarnih snovi, zlasti ko ob nesrečah pride do nenadzorovanega uhajanja teh snovi v okolje. Med potencialne vire obremenjevanja vodnih virov uvrščamo tudi bencinske servise, ki jih je bilo na obravnavanem območju leta 2003 osem. Vsi, razen dveh, so bili neprimerno zgrajeni in niso imeli urejenega odtoka odpadnih voda prek lovilcev olj.

Zaradi milega podnebja soljenje cest na Krasu ni intenzivno, a vendarle ima določen učinek na kraško podtalnico. Za posipanje se navadno uporablja natrijev klorid s primesmi in raztopino kalcijevega diklorida. Kloridom so pogosto primešane težke kovine in včasih celo živo srebro. Letna količina soli, ki jo cestna podjetja porabijo za posipanje državnih in lokalnih cest na Krasu, je okoli 740 t. Večjega onesnaženja podtalnice zaradi soljenja še niso opazili.

Prek obravnavanega območja poteka tudi približno 70 km železniških tirov. V letu 2002 je prek Krasa peljalo 28.105 potniških vlakov, kar je 40 odstotkov vseh prevozov po železnicah na Krasu (Medmrežje 3). Na Slovenskih železnicah ocenjujejo, da je bilo leta 2002 po železnici prek mejnih prehodov Fernetiči in Vrtojba ter Luke Koper prepeljanih skupno prek devet milijonov ton blaga, od tega je bilo šest odstotkov kemičnih proizvodov in devet odstotkov nafte in derivatov. Od tega je bilo največ nevarnih snovi prepeljanih na progi Koper–Ljubljana. Čeprav je prevoz nevarnih snovi po železnici varnejši kot po cesti, večji delež prepeljanega tovora še vedno sloni na cestnem transportu.

3.4 Kmetijstvo

Tradicionalno gospodarstvo je na Krasu, ki je bilo oskrbno zaledje Trsta, temeljilo na reji drobnice in poljedelstvu. Poljedelstvo je danes omejeno na obdelovanje majhnih njiv na dnu kraških depresij. Vse bolj prevladuje vinogradništvo, ki je v zadnjih desetletjih postalo najdonosnejša kmetijska panoga na Krasu. Vinogradi sicer obsegajo tri odstotke obdelovalnih zemljišč, večinoma v okolici Dutovelj, Tomaja, Križa, Avberja, Komna, Kobdilja in Utovelj. V občinah Komen in Sežana površina vinogradov skupno presega 450 ha. Vse bolj se uveljavlja tudi pridelava sadja v okolici Tomaja in Dutovelj (Medmrežje 2, Vrišer 2002).

Kmetijskemu obremenjevanju so najbolj izpostavljeni intenzivno obdelani vinogradi in sadovnjaki, kjer se uporablja največ umetnih gnojil in zaščitnih sredstev. Pri intenzivnem vinogradništvu sta količina in kakovost pridelka popolnoma odvisni od pravilne uporabe fitofarmacevtskih sredstev. Toda vinogradniki za doseganje večjih donosov pogosto uporabljajo prevelike količine kemičnih pripravkov (Rejec Brancelj 2001).

Na Krasu so stalen vir onesnaževanja tudi neurejena gnojišča, gnojne jame in nezavarovane zaloge hlevskega gnoja, od koder se izcedne vode koncentrirano stekajo v podzemlje. Razpršeni vir onesnaženja pa sta še gnojenje krmnih rastlin z mineralnimi gnojili in nekontrolirano gnojenje z gnojem ali gnojevko.

Živinoreja na obravnavanem območju nima večjega družbeno-ekonomskega pomena. Na obravnavanem območju ni večjih govedorejskih ali prašičjih farm, prevladujejo kooperacijski rejci perutnine, ki letno vzredijo 20.000–80.000 živali. Naselja, kjer živinorejska gostota presega 0,5 GVŽ/ha, so redka: Volčji grad, Lipa, Vojščica, Brestovica pri Povirju, Kazlje, Opatje selo, Lokev in Dutovlje. Naselja, ki presegajo 0,8 GVŽ/ha so Voglje, Štorje in Sveto (Medmrežje 4).

Kobilarna in turistično rekreativni center Lipica je domnevno največji obremenjevalec voda na Krasu. Center letno porabi 70.500 m^3 vode, okolje pa obremenjuje predvsem z neurejenimi odtoki odpadnih voda in izcednimi vodami iz hlevov. Odpadne vode so namreč speljane v zastarelo in premajhno čistilno napravo z mehanskim čiščenjem, od tam pa neposredno v naravo. Analize iztokov (Poročilo o obratovalnem monitoringu odpadnih voda 2002) so pokazale, da vrednosti BPK_5, KPK, celotnega fosforja, usedljivih snovi, nitritov in vsota tenzidov presegajo predpisane mejne vrednosti, predpisane za odpadne vode (Ur. l. RS 35/96).

3.5 Industrija

Na Krasu je do industrijskega razvoja prišlo šele po drugi svetovni vojni, zlasti v Sežani, Divači in Komnu. Toda gospodarsko recesijo v devetdesetih letih 20. stoletja je preživelo le nekaj obratov. Zato se je industrijsko onesnaževanje, ki je doseglo višek v osemdesetih letih, znatno zmanjšalo. Industrijske odplake so vir onesnaževanja, če zbiranje in čiščenje izcednih voda ni zagotovljeno oziroma ni učinkovito. Zato so k zmanjšanju obremenjenosti okolja z industrijskimi odplakami pripomogli sanacijski ukrepi, ki so jih številni obrati sprejeli z uvajanjem do okolja prijaznejših tehnologij.

Industrijska proizvodnja na Krasu je zgoščena predvsem v večjih naseljih. Najpomembnejši industrijski kraj je Sežana, kjer so prehrambena, tekstilna, kemična in gradbena industrija ter suhozemni terminal. V Divači je tovarna električnih aparatov in nekaj manjših industrijskih obratov. V Komnu je gradbena, v Dutovljah lesnopredelovalna, v Šepuljah pa mesnopredelovalna industrija.

Največja onesnaževalka kraških voda je pršutarna Kras v Šepuljah, ena izmed vodilnih mesnih industrij v Sloveniji. V proizvodnji letno porabijo 46.570 m^3 vode. Ker nimajo lastne čistilne naprave, vse tehnološke in odpadne vode brez predhodnega čiščenja odvajajo neposredno v naravo. Analize odpadnih voda so pokazale preveliko vsebnost težkohlapnih lipofilnih snovi oziroma maščobe, celotnega fosforja, klorida, BPK_5 in KPK (Poročilo o vzorčenju odpadne vode in terenskih meritvah 2001).

Tudi Mitol, tovarna lepil v Sežani, je zelo velik porabnik vode in proizvajalec tehnološke odpadne vode na Krasu, saj letno porabi 17.300 m^3. Imajo lastno čistilno napravo in urejeno čiščenje odpadnih voda. Tehnološko vodo najprej odvajajo v lastno čistilno napravo, nato pa v javno čistilno napravo. Izcedne vode ne presegajo predpisanih mejnih vrednosti (Poročilo o vzorčenju odpadne vode in terenskih meritvah 2002). Mitol pa je eden izmed največjih potencialnih onesnaževalcev kraških voda zaradi možnosti izlitja kemičnih sredstev. V dvoplaščnih rezervoarjih skladiščijo 250–300 t nevarnih snovi.

3.6 Turizem

Turistični potencial Krasa je izjemno bogat, ponudba in storitve pa skromne. Pokrajina leži v zaledju velikih obmorskih mest, kot sta Koper in Trst, zato ima velike možnosti za razvoj različnih oblik turizma.

Da bi bile obremenitve vodnih virov na Krasu zaradi turizma čim manjše, je smiselna ureditev razpršenih turističnih središč. Pri tem pa bi bilo potrebno skrbno pretehtati, kakšno stopnjo turističnega obiska Kras lahko sprejme v smislu povečane porabe pitne vode in s tem sanitarnih odplak, gradnje velikih hotelskih objektov in gostišč, parkirišč in prometnega omrežja.

4 Sklep

Kraška pokrajina se specifično odziva na antropogeno obremenjevanje. Prenos onesnaževal skozi zgornjo, nezasičeno cono poteka z različno hitrostjo. Snovi se tam lahko zadržujejo nekaj minut, lahko pa tudi več let. Nepredvidljivo je tudi potovanje onesnaževal skozi zasičeno cono, ker največkrat ne poznamo položaja glavnih prevodnih kanalov, ki prevajajo večino vodnega toka (Ford in Williams 1989, 518–521).

V krasu zato zelo težko predvidimo posledice različnih dejavnosti in posegov v prostor. Nedvomno pa neposredni odtok onesnaženih voda v kraški vodonosnik počasi, a vztrajno zastruplja zaloge pitne vode. V primeru odtekanja nevarnih in strupenih snovi lahko pride do trajnega onesnaženja izvirov, kakor se je zgodilo v primeru Krupe v Beli krajini (Polič s sod. 1999). Posebno pozornost moramo zato posvetiti človekovim raznovrstnim vplivom na kraške vode in preprečevanju oziroma zmanjšanju negativnih učinkov.

Kartiranje onesnaževalcev in ranljivosti podtalnice na kraških območjih je za državne in krajevne organe, ki so odgovorni za načrtovanje in odločanje o rabi prostora, koristna osnova za njihove odločitve. Čeprav v Sloveniji metodologija za izdelavo teh zemljevidov še ni uzakonjena, je na posameznih območjih že bilo narejenih nekaj študij (Janža in Prestor 2002; Petrič 2002).

Podtalnico na Krasu ogrožajo različni tipi onesnaževalcev, ki izhajajo iz različnih človekovih dejavnosti. Ocenjevanje in kartiranje onesnaževalcev upoštevata obstoječo in potencialno stopnjo škodljivosti za vsak tip onesnaževalca. Najpogostejši vir onesnaževanja so naselja brez urejenega odvajanja komunalnih voda. Večina stanovanjskih hiš na Krasu ima vgrajene greznice, ki niso zgrajene v skladu z zahtevami. Naselja ogrožajo kraško podtalnico še z neočiščenimi komunalnimi in gospodinjskimi odpadnimi vodami. V bližini naselij so številna divja odlagališča odpadkov, ki prav tako onesnažujejo podtalnico.

Pomemben onesnaževalec voda v primeru razlitij nevarnih snovi ob nesrečah so tudi prometnice, zlasti če prečkajo napajalno zaledje vodnega vira. Onesnaženje povzročajo tudi industrijske odpadne vode, še posebej v primerih, ko zbiranje odpadnih voda in njihovo čiščenje ni urejeno. Tak primer je pršutarna v Šepuljah. Kmetijstvo na Krasu z izjemo vinogradništva ni intenzivno in ni nevarno za onesnaževanje podtalnice. Vpliv pretirane in nepravilne uporabe gnojil ter zaščitnih sredstev v vinogradništvu na kakovost podtalnice pa nikakor ni zanemarljiv (slika 5).

Slika 5: Onesnaževalci kraške podtalnice na Krasu.
Glej angleški del prispevka.

Na Krasu niso najprimernejše razmere za varovanje kraške podtalnice zaradi gostejše poselitve (v primerjavi z Visokim Dinarskim krasom in z Alpskim krasom) in ogrožanja z različnimi tipi onesnaževalcev. Dodatni razlogi za pomanjkljivo varovanje podtalnice so povezani z nezadostnim upoštevanjem posebnih značilnosti pretakanja voda v krasu in velike ranljivosti kraških vodnih virov, z neurejeno vodovarstveno politiko (zlasti v preteklosti), z navzkrižnimi interesi uporabnikov prostora in tudi s pomanjkanjem znanja o trajnostnem ravnanju z vodnimi viri.

Ker so merilne točke onesnaženosti podtalnice v krasu zaradi heterogenih značilnosti kraških vodonosnih sistemov zelo redke, je odkrivanje dejanskih onesnaževalcev težavno. Zato za ugotavljanje onesnaženosti uporabljamo kemične in biološke analize vode na izvirih in v vrtinah. Čeprav so obsežne raziskave kraških vodonosnikov v Sloveniji redke, so kemične in biološke analize pokazale znake onesnaženja že v mnogih primerih (Kovačič in Ravbar 2005, 232).

Najpomembnejši vidik onesnaženja kraške podtalnice je onesnažena pitna voda. Analize pitne vode iz Klaričev so že pokazale povečano prisotnost koliformnih bakterij in bakterij *Escherichia coli*, čeprav znotraj predpisanih mejnih količin.

Če želimo ohraniti kakovostno pitno vodo tudi v prihodnje, je potrebno zagotoviti ustrezno zaščito vodnih virov. Pogoj za to so ustrezno izdelani zemljevidi ranljivosti kraških vodnih virov, ki temeljijo na kartiranju potencialnih in dejanskih onesnaževalcev. Zemljevidi onesnaževalcev so koristno praktično orodje pri nadaljnjem načrtovanju varovanja vodnih virov in rabe prostora.

5 Viri in literatura

Glej angleški del prispevka.