ACTA CARSOLOGICA	32/2	26	307-314	LJUBLJANA 2003

COBISS: 1.04

KARST AQUIFERS VULNERABILITY OR SENSITIVITY?

RANLJIVOST ALI OBČUTLJIVOST KRAŠKIH VODONOSNIKOV?

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Prejeto / received: 26. 8. 2003

Abstract UDC: 551.44:556.3

Gregor Kovačič & Nataša Ravbar: Karst aquifers vulnerability or sensitivity?

The concept of karst aquifer vulnerability mapping is commonly used for the determination of water protection zones and planning of land use in the background of the captured karst sources and wells. Several different methodologies for karst aquifer vulnerability mapping exist and the examination of scientific literature shows considerable variations in the definition of the term vulnerability. The authors suggest the distinction between the terms vulnerability and sensitivity of karst aquifers, since the former includes more information, which are required for efficient protection. The interpretation of the applied terms is founded on the conceptual background of the environmental vulnerability studies, which are declared with the Slovene 1993 Environmental Protection Act.
Key words: karst hydrology, karst terminology, protection of karst aquifers, self-cleaning capacity.

Izvleček UDK: 551.44:556.3
Gregor Kovačič & Nataša Ravbar: Ranljivost ali občutljivost kraških vodonosnikov?

Za določitev vodovarstvenih območij ter za načrtovanje rabe prostora v zaledju zajetih kraških izvirov in vrtin se praviloma uporablja koncept kartiranja ranljivosti kraških vodonosnikov. Obstaja več med seboj različnih metodologij kartiranja ranljivosti kraških vodonosnikov in pregled znanstvene literature ka•e na določene razlike v definiciji pojma ranljivosti. Avtorja predlagata razlikovanje med pojmoma ranljivost in občutljivost kraških vodonosnikov, saj prvi vsebuje več informacij, ki jih potrebujemo za primerno varovanje. Pri razlagi pojmov se avtorja opirata na konceptualna izhodišča študij ranljivosti okolja, ki so v Sloveniji opredeljene z Zakonom o varstvu okolja iz leta 1993.
Ključne besede: kraška hidrologija, kraška terminologija, varstvo kraških vodonosnikov, samočistilne sposobnosti.

INTRODUCTION

The concept of estimation of karst aquifer vulnerability is relatively young. According to the literature, in the early seventies of the last century the first aquifer vulnerability estimations were introduced and some researches were applied. Since then several other methods have been presented. Nevertheless, different professions still have diverse comprehension and interpretation about the term *vulnerability*. For this reason divergence and misunderstanding still appear and the unique definition of the term is not agreed yet.

In Slovenia the Environment protection Act, which was passed in the year 1993, requires Environmental vulnerability studies. Article 52 of the act specified the making of Environmental vulnerability studies, which are a direct response to the recommendations for sustainable development that were ratified by all the signers of Agenda 21. According to the methodological scheme of the environmental vulnerability study, devised under the instruction of a research team of geographers, it is necessary to assess the recovery and neutralizing or self-cleaning capacity of the environment and its components as well as of the extent and degree of the past anthropogenic interventions which have already reduced the environmental carrying capacity and consequently limited further interventions (Špes *et al.* 2002). The group of researchers from Biotechnical Faculty (University of Ljubljana) has made similar studies on the Environmental vulnerability studies in Slovenia (Marušič 1996).

Although estimation of *vulnerability / sensitivity* of karst aquifers is principally for land use planning in karst, previous research while estimating karst aquifer vulnerability only considered natural characteristic, while the extent and degree of the past human interventions has not been considered at all. The methodological scheme of the environmental vulnerability studies could be easily applied in karst groundwater vulnerability mapping, but it is necessary to distinguish between the terms **sensitivity** and **vulnerability**.

DISCUSSION

Examination of existing vulnerability mapping methodologies and descriptions of vulnerability in the scientific literature shows considerable variation in the definition and the usage of the vulnerability concept. Up to now there has been no generally accepted definition and methodology for the construction of vulnerability maps. The concept of karst aquifer vulnerability to contamination has different meanings for different researchers. Some view it as an intrinsic characteristic of soils and other parts of natural environment. Others find that vulnerability depends on the properties of individual contaminants or contaminant groups, but is independent of specific land use or management practices. Still others associate vulnerability with a specific set of human activities on the land surface. Because of the variations in the definitions, the term *vulnerability* should be clearly defined. Some authors have attempted to avoid the term vulnerability altogether and have substituted terms such as *sensitivity* (Gogu & Dassargues 2001; COST 65 1995).

According to the Environmental vulnerability studies, the term *natural sensitivity* of the environment and its components was applied. In the sense of establishing an efficient protection of highly sensitive karst aquifers we suggest to apply the term **natural sensitivity of karst aquifers** to pollution in the concept of karst source and resource vulnerability mapping. Regarding the Environmental protection Act, the natural sensitivity should be defined as the assessment of **self-**

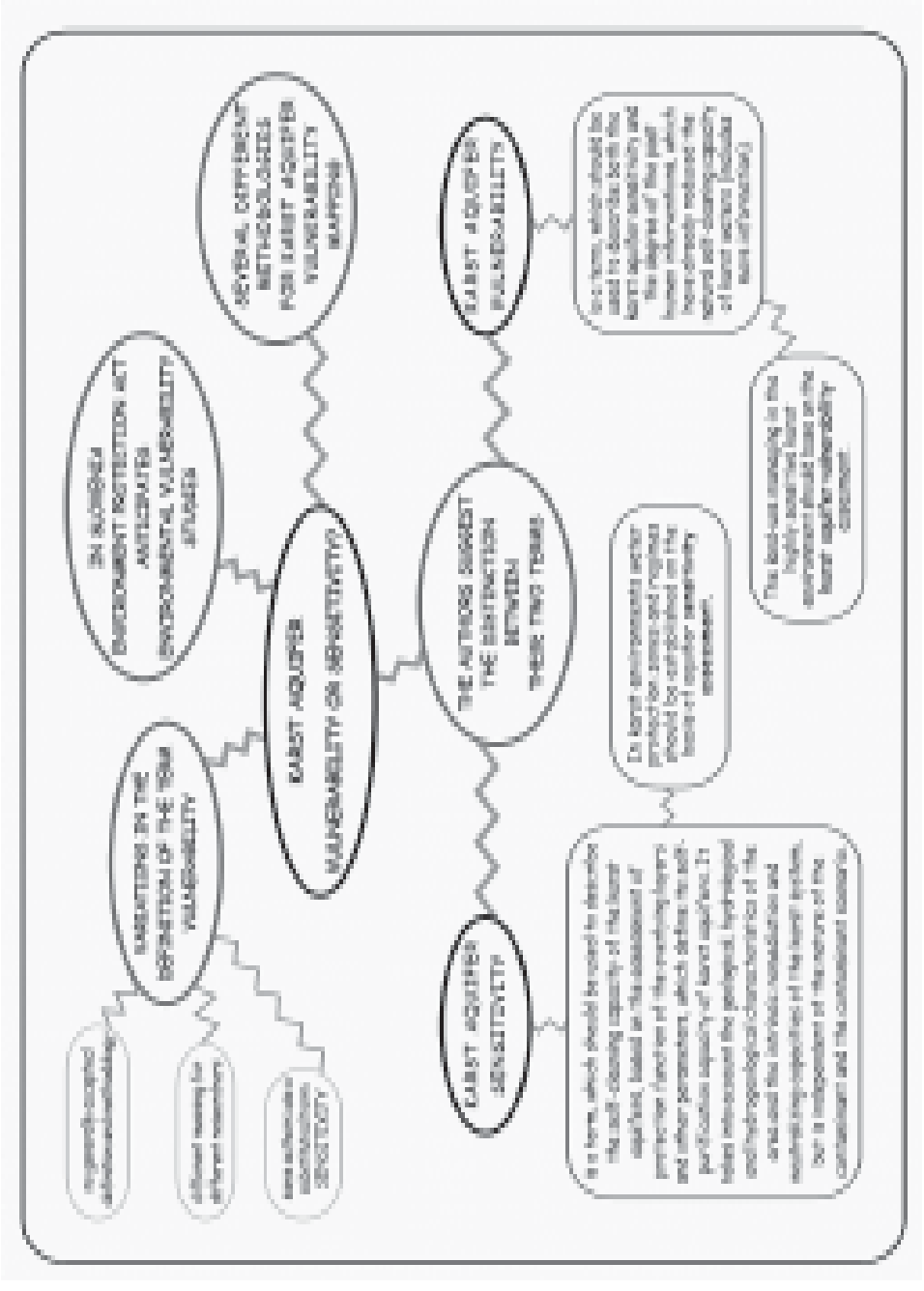

Fig. 1: The concept of karst aquifer vulnerability and karst aquifer sensitivity.
Sl. 1: Koncept ranljivosti in občutljivosti kraških vodonosnikov.

cleaning capacity of the karst environment, based on the assessment of protection function of the overlying layers and other parameters, which defines the self-purification capacity of karst aquifers (concentration of flow, karst network development, precipitation regime, etc.). The self-cleaning capacity of the karst aquifers is the intrinsic characteristic of karst environment, which determines the ability of the karst environment to reduce negative influences of contamination and to re-establish the equilibrium of the environment.

It takes into account the geological, hydrological and hydrogeological characteristics of the area and the intrinsic recovery and neutralizing capacities of the karst system, but is independent of the nature of the contaminant and the contaminant scenario. The synonym is the term **intrinsic vulnerability,** which defines the geological, hydrological and hydrogeological characteristics of an aquifer, without consideration of the attributes and behavior of particular contaminants (Vrba & Zaporozec 1994; COST Action 620 2002).

The measurements of physical-chemical and microbiological characteristics of the captured karst sources and pumping wells show that the karst groundwater is already polluted to some degree. This indicates that in some karst areas the degree of the environmental anthropogenic impacts has already exceeded the natural self-cleaning capacity of karst aquifers. Therefore the term **vulnerability of karst aquifers** should be applied, describing both the natural sensitivity and the degree of the past human interventions, which have already reduced the natural recovery and neutralizing capacity of karst waters. It is important to apply the extent and degree of the past anthropogenic interventions in the concept of karst aquifer vulnerability assessment in order not to lose important information, since the response of the karst environment on the certain future human intervention could depend on the existent contamination in a great extent.

Water protection zones and regimes should be established on the basis of aquifer **sensitivity assessment**, while the land use management in the highly sensitive karst environment should be based on the **karst aquifer vulnerability** and not **sensitivity** assessment, since the former is a much more complex indicator and includes, beside, the assessment of carrying capacity, also the information on actual hazards that already contaminate karst groundwater. By applying the karst aquifer **vulnerability** assessment as discussed above in the concept of the protecting of the karst aquifers fewer mistakes in land use management are to be expected (e.g. placing of potential hazards in the karst areas of high vulnerability).

CONCLUSION

In order to summarize these ideas, we recommend the usage of the following definitions of the terms karst aquifer sensitivity and karst aquifer vulnerability in the field of protection zoning and land use managing in karst environments.

Karst aquifer sensitivity is a term, which should be used to describe the self-cleaning capacity of the karst aquifers, based on the assessment of protection function of the overlying layers and other parameters, which defines the self-purification capacity of karst aquifers (concentration of flow, karst network development, precipitation regime, etc.). It takes into account the geological, hydrological and hydrogeological characteristics of the area and the intrinsic recovery and neutralizing capacities of the karst system, but is independent of the nature of the contaminant and the contaminant scenario.

Karst aquifer vulnerability is a term, which should be used to describe both the karst aquifer sensitivity and the degree of the past human interventions, which have already reduced the natural self-cleaning capacity of karst waters.

Karst aquifers are, due to their specific structure, particularly susceptible to pollution. Hence the protection of karst groundwater, which forms an important drinking water resource in many countries around the world and specially in Europe, is becoming an essential part of environmental management. Since the karst areas are often very large it is thus impossible to demand the maximum protection for the entire hydrogeological background of the source or the pumping well. This leads to the concept of groundwater vulnerability mapping, where different degrees of vulnerability (sensitivity) are symbolized by different colours. Such maps are a practical tool for land use management and protection zoning. **Karst aquifer vulnerability** includes more information about both the natural characteristics of karst aquifers and human impacts in comparison with the term karst aquifer sensitivity. This is the reason why planning of the future development in the certain karst environment should be based on karst aquifer vulnerability assessment.

REFERENCES

COST action 620, 2002: Final Report of Working Group 1 (Intrinsic Vulnerability) - 2nd Draft.- Compiled by Nico Goldscheider, 76 p., (unpublished).

COST action 65, 1995: Hydrogeological aspects of groundwater protection in karstic areas. Final report.- European Commission, Report EUR 16574 EN, Directorat-General: Science, Research and Development, 446 p., Brüssel, Luxemburg.

Environment protection Act. 1993: Official Gazette of the Republic of Slovenia, 32, 1750-1769.

Gogu, R. C. & A. Dassargues, 2001: Intrinsic vulnerability maps of a karstic aquifer as obtained by five different assessment techniques: comparison and comments. - 7th Conference on Limestone Hydrology and Fissured Media, 161-166. Besançon

Marušič, I., 1996: Študija ranljivosti okolja. Pojasnjevalno besedilo pripravljeno za delavnico in dodelavo modelov ranljivosti v septembru 1996.- Biotehniška fakulteta, Inštitut za krajinsko arhitekturo, 8 p., Ljubljana,

Špes, M., Cigale, D., Lampič, B., Natek, K., Plut, D. & A. Smrekar, 2002: Študija ranljivosti okolja. (Metodologija in aplikacija). - Geographica Slovenica 35, 1-2. Zalo•ba ZRC. Ljubljana, 150 p.

Vrba, J. & A. Zaporozec, 1994: Guidebook on mapping groundwater vulnerability. International association of hydrogeologists. Verlag Hienz Heise.Vol. 16, 131 p., Hannover.

RANLJIVOST ALI OBČUTLJIVOST KRAŠKIH VODONOSNIKOV?

Povzetek

Kraški vodonosniki so zaradi svoje specifične zgradbe posebno občutljivi na onesna•evanje. Varovanje kraške podtalnice, ki predstavlja pomemben vir pitne vode v številnih dr•avah sveta, še posebej v Evropi, pa pri načrtovanju rabe tal na krasu stopa vedno bolj v ospredje. Kraška območja so običajno zelo obse•na, zato je maksimalno zaščito za celotno zaledje posameznih kraških izvirov in vrtin nemogoče zahtevati in izvajati. To vodi h konceptu kartiranja ranljivosti kraških vodonosnikov, kjer so različne stopnje *ranljivosti / občutljivosti* krasa na onesna•enje simbolično prikazane z različnimi barvami. Karte ranljivosti tako predstavljajo podlago za določevanje vodovarstvenih pasov ter načrtovanje rabe prostora na krasu. Toda termin ranljivost kraške podtalnice si posamezni raziskovalci različno razlagajo, zato ta strokovni izraz še ni jasno opredeljen. Ravno tako še nimamo splošno uveljavljene metodologije za izdelavo kart ranljivosti. Ranljivost nekateri pojmujejo kot odraz bistvenih geoloških in hidrogeoloških značilnosti območja, drugi pa vključujejo tudi rabo tal v zaledju vodnih virov in njeno načrtovanje. Nekateri avtorji menijo, da je ranljivost vodonosnikov odvisna od lastnosti in obnašanja posameznih onesna•eval oziroma skupine onesna•eval v kraškem sistemu in je v tem smislu neodvisna od rabe prostora v zaledju. Zaradi različnih razlag je potrebno termin ranljivost natančneje opredeliti.

Namen tega prispevka je osvetliti razlike med **občutljivostjo** in **ranljivostjo kraških vodonosnikov.** Podlago za razpravo o pomenu obeh terminov predstavlja Zakon o varstvu okolja iz leta 1993. Z njim je Slovenija predvidela izdelavo študij ranljivosti okolja, ki pomenijo neposreden odgovor na priporočila o sonaravnem razvoju, ki so jih potrdile vse dr•ave podpisnice Agende 21. Metodologija za zakonsko opredeljene študije ranljivosti okolja, ki jo je izdelala geografska raziskovalna skupina, predvideva oceno naravne regeneracijske in nevtralizacijske oziroma samočistilne sposobnosti okolja in njegovih sestavin, kakor tudi obseg in stopnjo dosedanjih človeških posegov, ki •e zmanjšujejo njihovo nosilnost in s tem tudi omejujejo nadaljnje posege (Špes s sodelavci 2002).

Dejstvo je, da je potrebno razlikovati med pojmoma občutljivost in ranljivost kraških vodonosnikov in natančneje zakoličiti njun pomen. Kvalitetna osnova za terminološko nedorečenost in hkrati podlaga za koncept kartiranja ranljivosti kraških vodonosnikov je lahko metodološka zasnova študije ranljivosti okolja. Strokovni izraz **občutljivost kraških vodonosnikov** je določen kot ocena samočistilnih sposobnosti kraškega okolja, ki temelji na oceni varovalne funkcije zaščitnih pokrovov in ostalih kazalcev, ki vplivajo na samočistilno sposobnost kraških vodonosnikov (koncentracija toka, razvitost kraškega sistema, padavinski re•im, itd.). Občutljivost upošteva geološke, hidrološke in hidrogeološke značilnosti kraškega sistema in njegove naravne nevtralizacijske in regeneracijske sposobnosti, vendar je neodvisna od lastnosti in obnašanja posameznih onesna•eval. Sinonim za občutljivost je pojem *notranja ranljivost* (intrinsic vulnerability), ki ga je vpeljala skupina raziskovalcev v projektu COST Action 620.

Fizikalno kemijske in mikrobiološke analize zajetih kraških izvirov in črpalnih vrtin ka•ejo, da je kraška podtalnica do določene mere •e onesna•ena. To pomeni, da je ponekod obremenjevanje •e preseglo naravne samočistilne sposobnosti kraških vodonosnikov. Predlagamo, da se pojem **ranljivost kraških vodonosnikov** uporablja za označevanje lastnosti kraških vodonosnikov, ki

odra•a tako občutljivost, kakor tudi •e dose•eno stopnjo dosedanjih človeških vplivov, ki •e zmanjšujejo naravne regeneracijske in nevtralizacijske sposobnosti kraških voda. Izdelovanje vodovarstvnih con v zaledju zajetih kraških izvirov in vrtin ter pripadajočih re•imov varovanja bi moralo temeljiti na oceni občutljivosti kraških vodonosnikov. Načrtovanje rabe tal na kraških območjih pa mora sloneti na oceni ranljivosti kraških vodonosnikov, saj ranljivost poleg informacij o samočistilnih sposobnosti kraških voda vsebuje tudi podatke o •e dose•eni stopnji onesna•enja. Tak koncept varovanja količinsko bogatih zalog razmeroma visoko kakovostne pitne vode iz kraških vodonosnikov, se zdi zelo smiseln, saj preprečuje postavitev potencialnih občasnih in stalnih onesna•evalcev kraške podtalnice v območja, kjer obremenjevanje •e presega naravne samočistilne sposobnosti in se ka•e z onesna•enjem v zajetjih.