THE CRITERIA FOR DEFINING KARST GROUNDWATER PROTECTION AREAS

KRITERIJI ZA DOLOČANJE VARSTVENIH OBMOČIJ KRAŠKE TALNE VODE

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Acta Carsologica, XXIV (1995), 279-289, Ljubljana 1995

Izvleček UDK 556.338.2

Jože Janež: Kriteriji za določanje varstvenih območij kraške talne vode

V kraških vodonosnikih ni mogoče določati varstvenih območij s pomočjo časa razgradnje kateregakoli onesnaženja, tudi bakteriološkega ne. Predlagamo, da bi ranljivost različnih delov hidrološkega zaledja določali s časom, ki je na voljo za intervencijo ob odkritju onesnaženja, oziroma časom za preprečitev vstopa nevarne snovi v vodonosnik in v vodovodni sistem. Na obseg varstvenih območij bistveno vpliva poleg hidrogeoloških značilnosti hidrološkega zaledja tudi njegova raziskanost. Kriterij za določanje površine varstvenih območij so razmere ob visokih hidroloških stanjih (največje hitrosti, najvišja gladina, največja površina hidrogeološkega bazena).

Ključne besede: krasoslovje, hidrologija krasa, varstvo kraške talne vode

Abstract UDC 556.338.2

Jože Janež: The criteria for defining karst groundwater protection areas

It is not possible to define the karst aquifers protection areas by using the parameter of degradation time of any kind of pollution, including bacteriological contamination. We suggest that the demarcation of the protection areas is based on the vulnerability of the aquifer, which is determined as the time interval between the moment when pollution started and the moment when it is already too late to intervene (to prevent the admittance of dangerous material into an aquifer or water supply system). The extent of protection areas depends on hydrological characteristics of hydrological background as well as on the degree to which it is discovered. The extent of protection areas has to be defined at conditions of high hydrological situations (the highest water-speed, the highest water-level, the greatest extent of hydrogeological basin).

Key words: karstology, karst hydrology, karst groundwater protection

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INTRODUCTION

The article deals with the professional difficulties regarding preventive protection i. e. defining karst water resource protection areas. We consider the criteria for defining protection areas have not been studied sufficiently. We think, in future, these criteria must receive greater attention to be quantified to the greatest extent possible. In the article, four different criteria are discussed: the water stay-time interval, the extent to which the hydrological catchment area has been researched, the degree of danger for groundwater pollution and the time interval available to prevent ground water pollution.

CRITERIA

Water flow-time interval

The catchment area is the ground area from which all the water streams, on the surface as well as underground, flow off towards a certain spring. When defining protection areas in intergranular aquifers the catchment area of the karst springs is mostly divided into different degrees of danger for groundwater pollution, regarding "the time interval of water-flow within the limits of the protection area and the spring". The time interval necessary for the degradation of bacteriological contamination is used as the basis, i. e. the time interval sufficient for the microorganisms to lose their pathogenic characteristics. An extremely large span has been quoted or used for this time interval by different authors. The time interval of one to two months was used by Breznik (1976) to divide between the first and the second protection area in intergranular aquifers. It was quoted by Lacković (1986) that bacteria lose the pathogenic characteristics within 50 to 60 days, while 200 days with the bacteriological contamination of lower intensity and 400 days with intensive and permanent bacteriological contamination were cited by Filipović & Vujasinović (1982). According to Fritz & Pavičić (1986) the time interval necessary for the water to flow from the contamination infliction to the spring is one of the most important parameters for the karst springs as well. Surely the transfer time interval for the dangerous material is one of the basic physical factors to be taken into account with hydrological research. Nevertheless, it has limited applicability in karst underground water protection as the water speed in the karst is so great as not to allow adequate degradation of even the quickest degradable organic materials in the aquifers of natural size when the water level is high.

The 0,4 - 3,1 cm/s (14,4 - 111,6 m/h) apparent water speed levels of the tracing tests in Switzerland were quoted by Zupan & Gospodarič (1980). The results of tracing tests in Slovenia establishing apparent speed values (V_f) between 0,01 and 24,8 cm/s (0,36 - 893 m/h) were collected by Novak (1985), the average being 2,1 cm/s (75,6 m/h). In the Dinaric karst V_f is in the span between 0,002 and 55,2 cm/s (0,07 - 1987 m/h), the most frequent class being 1 - 2 cm/s (36 - 72 m/h) (Milanović, 1979). At $V_f > 0,5$ cm/s a distance of nearly 13 km is reached by water within 30 days, at $V_f > 1$ cm/s (according to Milanović (1979) 88,7 % of all cases) a distance of 26 km.

In the contamination degrading time interval such distances are reached by the groundwater as to make this criterion only one among the possible additional criteria to distinguish between the farthest and least threatened areas and the areas with the higher degree of danger for pollution, with the karst aquifers as well as fissure aquifers. It would be a reasonable choice to have, as suggested by Fritz & Pavičić (1986), definite criteria for each protection area, which should be the same ones for all the water springs in the karst.

THE CRITERION OF THE PROVED CATCHMENT AREA OF A KARST SPRING

According to the criterion of the catchment area of a karst spring established through research the following areas can be divided:

- proved catchment area of the karst spring (through the tracing test or other hydrological or geological proof),
- not proved but possible catchment area,
- proved out-of-catchment area (fig. 1).

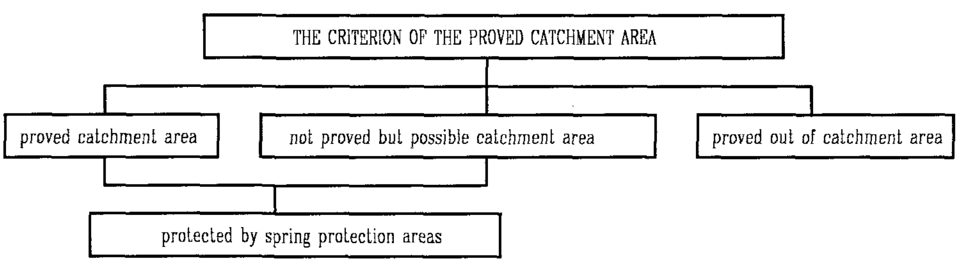

Fig. 1. The criterion of the proved catchment area

It appears to be reasonable to attribute to the not proved catchment areas of the karst spring the degree of pollution danger possible, regarding the existing hydrological circumstances, in case of the proved connection. If there are sinking streams with possible direct connections in such an area, it must be ranged among the areas of high pollution danger, otherwise among the medium or less endangered areas. Through further, more detailed research, the not-proved catchment area of the karst spring can be eliminated from the protected area or it can be appointed a milder protection regime.

Among the particular protection areas inside the whole protected area, the priority principle of the inner protection area is in force, which means the more rigorous protection regime is in force for the areas not clearly distinguishable as belonging to either one or the other degree of pollution danger.

POLLUTION DANGER AND THE TIME INTERVAL AVAILABLE TO INTERVENE

The pollution danger of the karst water depends on the burdening of the environment and the natural vulnerability of the aquifer (fig. 2).

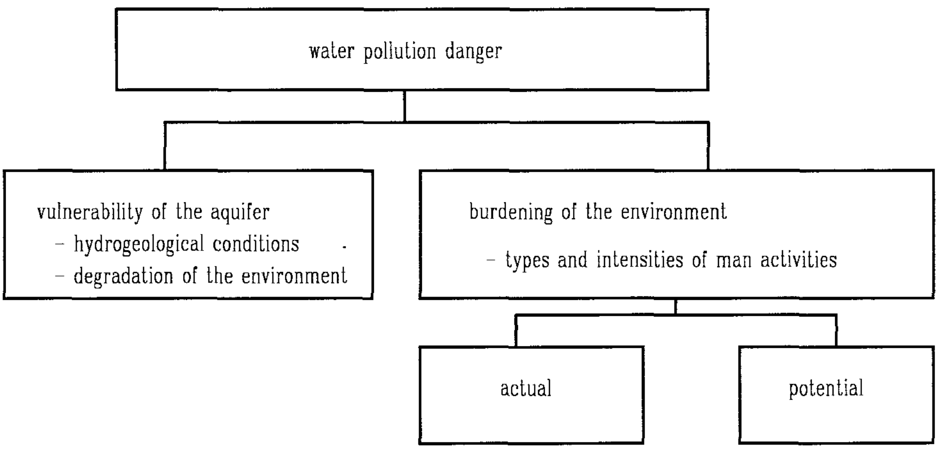

Fig. 2. Pollution danger of a karst aquifer

The burdening of the environment is caused by various types and intensities of human activities, latent and active. The natural vulnerability of the karst aquifer depends on the surface infiltration and hydrogeological conditions in the aquifer (way and time of underground water flow, water quantities, degree of dilution) and on the already reached degree of environmental degradation.

The vulnerability of the aquifer is used as the main criterion to classify the catchment area of the karst spring into protection areas. It is divided into four degrees: areas of catastrophic vulnerability, areas of great vulnerability, areas of medium vulnerability, and areas of little vulnerability (fig. 3).

This division corresponds almost fully with Šarin's (1986) area division, according to the pollution danger, into the following kinds of areas: the highly threatened ones (= great vulnerability), the endangered ones (= medium vulnerability), the partly threatened ones (= little vulnerability), and the non-threatened areas.

Through this division into the above four degrees of aquifer vulnerability we are able to prescribe the necessary criteria or conditions respectively as well as the corresponding protection area for each degree.

As the criterion of the parameter of degradation time for dangerous materials does not allow the differentiation of different degrees of pollution danger, and through that the protection areas, the degree of aquifer vulnerability is defined by the time interval available to intervene.

Intervention is required in the case of a sudden accidental or intentional release of dangerous material onto the surface. Usually the admittance of dangerous material at a certain spot is the problem, taking place once and only lasting a short time. Most frequently, it is caused by an unconventional permanent pollutant. Intervention can also be required in the case of conventional pollution (e.g. unexpected fertilisation, road construction in the catchment area of a karst spring), but also in the case of heavy rainfall after a longer dry period, when the washout of dangerous materials, which have been accumulating onto the surface or aquifer more or less continually, is increased.

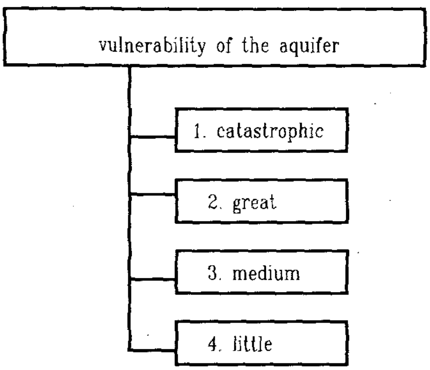

Fig. 3. The vulnerability of the aquifer

It is the intervention aim:

- to prevent the spread of dangerous material across the surface and its

irruption into the aquifer,
- to prevent admittance of dangerous material into a spring, a well or into the water supply system (to the consumer).

Usually, accidental events take place and can be expected in the production, transport, storage, processing and usage of dangerous materials (Kokol, 1980), which we have to take account of when organising preventive activities in protection areas.

When defining protection areas, we will not be interested in the sanction activity mode, contents or scope but in the time interval at disposal to intervene. The time interval available to intervene depends only on characteristics of the aquifer and of the dangerous material:
- the permeability of the surface and aquifer,
- the hydrological parameters (flow, stream speed, stream direction),
- the distance between the pollution point and the spring,
- climatic and hydrological circumstances,
- characteristics of the dangerous material.

From the point of view of protection, the karst spring catchment area can be divided into:
- the areas inside which there is practically no time to prevent the admittance of dangerous material into the water supply system after the pollution event,
- the areas inside which there is practically no time to prevent the admittance of dangerous material into the aquifer after the pollution event, but there is a certain time interval to prevent the admittance of the material into the water supply system,
- the areas inside which there is a certain time to prevent the admittance of dangerous material into the aquifer after the pollution event (fig. 4).

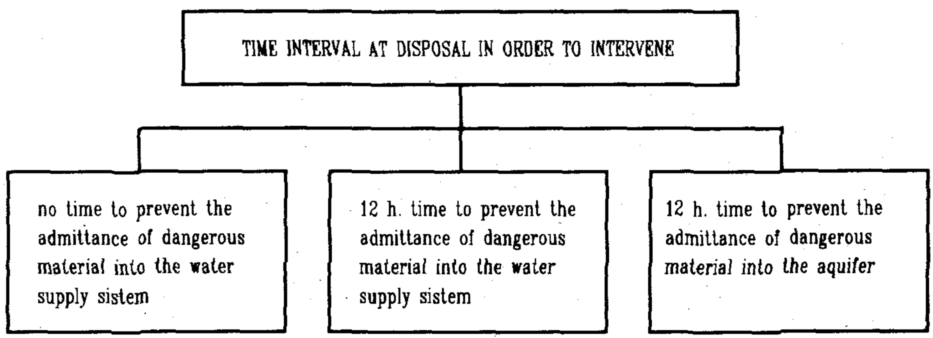

Fig. 4. Time interval available in order to intervene in case of pollution

Defining the time interval available to prevent the admittance of dangerous material into the water supply system or the aquifer should be based on the speed of water flow through the aquifer and the time interval necessary to degrade or absorb the non-lasting dangerous materials. However, as already stated, the water speed levels in the karst aquifers and fissure aquifers are such as not to allow any of the dangerous materials infiltrated into the hydrological basin to be degraded or absorbed sufficiently as far as the spring or well. This is why the time available to intervene should be based on the convention taking into account also the actual time interval during which the water supply system management or any other service can intervene in case of emergency. The time interval during which the intervention is feasible depends upon the state of the water supply service organisation as well as upon the characteristics of the place in which the disaster has occurred. Therefore the time available to intervene (12 hours) is presented as the proposal taking both conditions into account.

The catastrophic vulnerability of the aquifer applies for the areas inside which there is practically no time (up to 4 hours) to prevent the admittance of dangerous material into the water supply system after the pollution has occurred.

The great vulnerability of the aquifer applies for the areas in which there is practically no time to prevent the admittance of dangerous material into the aquifer after the pollution taking place; there is, however, a certain time interval (12 hours, a suggestion) in which the admittance of dangerous material into the water supply system can be prevented.

The medium degree of danger for groundwater pollution applies for the areas inside which there is a certain time interval (more than 12 hours) to prevent the admittance of dangerous material into the water supply system after admittance of dangerous material into the aquifer has taken place.

The little vulnerability of the aquifer applies for the areas:

- inside which there is a certain time interval (12 hours, a suggestion) to prevent the admittance of dangerous material into the aquifer after the pollution taking place, or
- where the concentration of the dangerous material in actual potential quantity is lowered below the maximum allowed concentration level defined by law, within the distance from the admittance point to the spring (fig. 5).

Above all, vulnerability in a certain area is affected by the hydraulic permeability of the aquifer. Regarding hydraulic permeability from the standpoint of defining protection areas, too, there can be distinguished: the karst aquifers and areas (limestone, chiefly), the fissure aquifers and areas (dolomite, mostly) and the poorly permeable and non-permeable areas (e.g. flysch). Each of the degrees of danger for groundwater pollution can be described additionally, applying characteristics defining the aquifer permeability.

The areas of great vulnerability are defined by exceptionally great permeability, the areas of medium vulnerability by medium permeability, and the areas of little vulnerability by low permeability. Naturally, when defining the danger for aquifer pollution, figures other than hydraulic permeability must also be considered (the depth to the groundwater piezometric level, the stated groundwater speed, the distance from the pollution source to the karst spring etc.).

It is possible but difficult to define the degree of danger for groundwater pollution according to the water quantity contributed to the total spring flow by the different parts of the catchment area. Usually, there are not sufficient data for such a definition (the not sufficiently dense ombrographic net, the lack of data about hydraulic permeability etc.). It is possible to estimate the degree of danger according to the sinking stream flow, though.

The extent of protection areas has to be defined at conditions of high hydrological situations (the highest water speed, the highest water level, the greatest extent of hydrological basin).

A certain protection area with the corresponding protective regime applies for each degree of aquifer vulnerability (fig. 5).

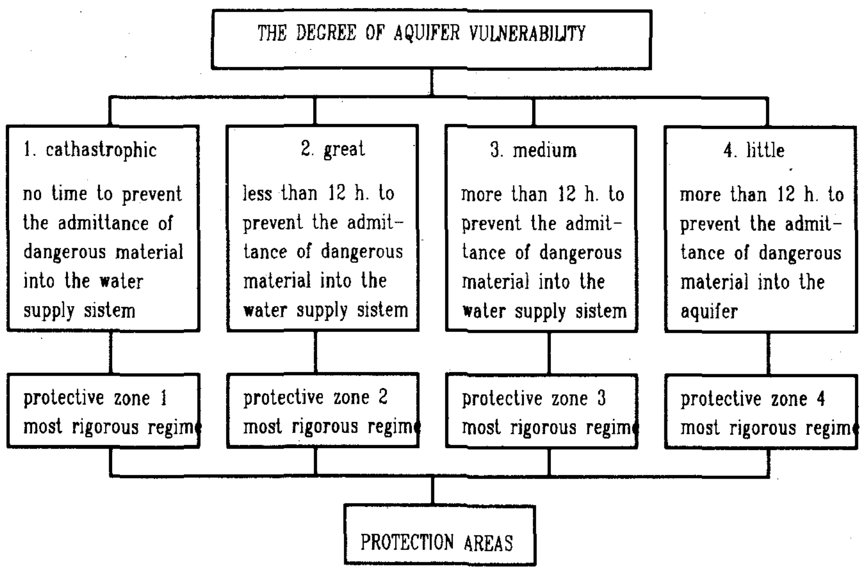

Fig. 5. The connection between the vulnerability of the aquifer and karst spring protection areas

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KRITERIJI ZA DOLOČANJE VARSTVENIH OBMOČIJ KRAŠKE TALNE VODE

Povzetek

V praksi običajno naletimo na velike težave pri določanju varstvenih območij kraških vodnih virov, saj temu problemu doslej ni bilo posvečeno dovolj pozornosti. Pri medzrnskih vodonosnikih najbolj pogosto privzamemo kriterij časa toka vode znotraj meja varstvenega območja. Za osnovo je uporabljen čas, ki je potreben za degradacijo bakteriološkega onesnaženja. Ta kriterij ima v krasu omejeno uporabnost, saj zaradi prevelike hitrosti toka ob visokih vodah ni možen ustrezen razkroj niti najhitreje razgradljivim organskim snovem. Bolj smiselna se nam zato zdi kombinirana raba 4 različnih kriterijev: časa toka vode skozi vodonosnik, stopnje raziskanosti hidrogeološkega zaledja, stopnje nevarnosti onesnaženja podzemne vode ter časa, ki je na voljo za preprečitev onesnaženja podzemne vode.

Kriterij časa toka vode skozi vodonosnik uporabljamo v krasu le kot pomožni faktor za ločevanje najmanj in najbolj ogroženih območij. Glede na stopnjo raziskanosti so lahko območja v zaledju kraških izvirov: dokazano znotraj zaledja, možno, a ne dokazano znotraj zaledja ter dokazano izven zaledja. Smiselno je, da območjem, ki jih sicer uvrščamo v zaledje, a za to nimamo zadostnih dokazov, priredimo tako stopnjo nevarnosti onesnaženja, kot da bi bile zveze dokazane. Če pa se ne moremo odločiti za primerno stopnjo nevarnosti onesnaženja, izberemo možnost strožjega režima.

Nevarnost onesnaženja kraških vod je odvisna od obremenjenosti okolja in naravne ranljivosti vodonosnika. Glavni kriterij za klasifikacijo zaledij v varstvena območja je ranljivost, ki je lahko katastrofična, velika, srednja in majhna. Kriterij za razvrščanje v te razrede je čas, ki je na voljo za intervencijo ter je odvisen od karakteristik vodonosnika in lastnosti nevarnih snovi, ki povzročajo onesnaženje. Pri katastrofični ranljivosti ni časa za preprečitev vstopa nevarnih snovi v sistem vodooskrbe, zato taka območja uvrščamo v 1. varstveno območje z najstrožjim režimom. V 2. varstvenem pasu so območja velike ranljivosti, kjer je za intervencijo na razpolago manj kot 12 ur. Za srednjo ranljivost je značilno, da imamo več kot 12 ur časa za preprečitev vstopa nevarnih snovi v sistem vodooskrbe in jih uvrščamo v 3. varstveno območje. Pri majhni ranljivosti je za preprečitev vdora nevarnih snovi v vodonosnik na voljo več kot 12 ur, zato imajo ta območja znotraj 4. varstvenega pasu najmanj strog režim zaščite. Izbiro intervala 12 ur predlagamo na osnovi ocene stopnje organiziranosti službe za nadzor vodovodnega sistema in karakteristik območja, v katerem se onesnaženje pojavi.