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Integrated approach to delineation of drinking water protection zones

Integrirani pristop k določanju vodovarstvenih območij

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Abstract

Protection of water resources plays an important role in providing safe and reliable drinking water for people and industry. Drinking water resource protection usually comprises active and passive measures. Passive measures, consisting of different protection zones surrounding the recharge area of the drinking water abstraction point, are the most important and most widely used measures. In the paper is illustrated how the protection of drinking water is implemented through the Water Framework Directive. Protection zones are defined based on the classification of drinking water resource types. They are divided into two groups; groundwater and surface water bodies. All of them are further divided into subgroups; groundwater into intergranular, karstic and fissured aquifers; surface water into stagnant and flowing water bodies. For all drinking water resources three protection zones are defined: inner, middle and outer zone. The outer zone was defined as the total recharge zone of the water quantities abstracted. Inside of inner zone, abstraction point zone is defined, which is protected from unauthorized access. Protection zones for intergranular aquifers are determined according to the isochrones based on travel times. Karstic aquifers are protected on the basis of intervention times and the level of the recharge zone karstification. Fissured aquifers are protected according to groundwater flow velocities; if the flow is laminar, the method of intergranular aquifers is used, otherwise the method of karstic aquifer is implemented. For surface water protection zones limitation method of distances, method of isochrones and dilution and method of intervention times are used.

Izvleček

Zaščita vodnih virov igra pomembno vlogo pri zagotavljanju zdrave in zanesljive oskrbe prebivalstva in industrije s pitno vodo. Zaščita virov pitne vode običajno obsega aktivne in pasivne zaščitne ukrepe. Pasivni ukrepi, ki se sestoje iz zaščitnih območij, ki obkrožajo zajetje, predstavljajo enega najbolj pogostih ukrepov za zaščito. V članku je prikazano kako je zaščita vodnih virov implementirana na podlagi evropske Okvirne direktive o vodah. Zaščitna območja temeljijo na klasifikaciji virov pitne vode. Razdeljeni so na dve skupini; podzemna in površinska vodna telesa. Ti dve glavni skupini pa sta nadalje razdeljeni na podskupine; podzemne vode na medzrnske, kraške in razpoklinske vodonosnike, površinske vode na stoječa in tekoča vodna telesa. Za vsako od vodnih teles so definirana najožje, ožje in širše območje. Širše območje je opredeljeno kot celotno napajalno zaledje. Znotraj najožjega območja je določeno območje zajetja, ki mora biti zaščiteno pred kakršnim koli posegom nepooblaščene tretje osebe. Zaščitna območja v medzrnskih vodonosnikih so določena na podlagi izohron in časov dospetja. Kraški vodonosniki so zaščiteni na podlagi intervencijskih časov in stopnje zakraselosti napajalnega zaledja. Razpoklinski vodonosniki so zaščiteni na podlagi hitrosti toka podzemne vode, če je tok laminaren, se uporabijo metode za medzrnske vodonosnike, v nasprotnem primeru pa metode za kraške vodonosnike. Pri površinskih vodnih telesih so uporabljene metode razdalj, metode izohron, metode razredčenj ter metode intervencijskih časov.

Introduction

Protection of water resources plays an important role in providing safe and reliable drinking water for people and industry. Drinking water resource protection is usually represented by active and passive measures. Passive measures that consist of different protection zones surrounding the recharge area of the drinking water abstraction point are the most important and most widely used measures. Passive measures are commonly upgraded by active measures. Among active measures technical arrangements such as inflow wells or active barriers in the recharge zone can be defined. They are very costly and used only in large urban areas. Practices of drinking water protection zones are in a very general view well established. Yet, a more precise insight into zoning practices worldwide shows that several different procedures are established and that the zones are regulated very differently. With the present efforts in establishing and implementing new European water law regulations by the Directive 2000/60/EC, establishing a framework for Community action in the field of water policy – the Water Framework Directive (Anonymous, 2000a), new energy has been put to review and audit existing drinking water protection practices in the Member States as well as on the European level.

The Water Framework Directive (Anonymous, 2000a) presents big step forward in the protection of water resources. The Directive requires from the Member States of the European Union implementation of great efforts in developing new water management strategies. To Member States protection of groundwater is an important part of the Directive's requirements and obligations. Groundwater resources are understood as an important source of drinking water, as an integral part of hydrologic cycle and other environmental compartments. Drinking water protection is specifically considered in the Directive in Articles 6 and 7. Especially it is established in Article 7.3 that "Member States shall ensure the necessary protection for the bodies of water identified with the aim of avoiding deterioration in their quality in order to reduce the level of purification treatment required in the production of drinking water. Member States may establish safeguard zones for those bodies of water."

Slovenia is one of the countries in Central Europe that are abounding with water due to the vicinity of the Alps. Geological conditions represented mainly by big alluvial depressions, carbonate and other sedimentary rocks also contribute to groundwater abundance; therefore drinking water is predominantly supplied from groundwater resources. On the state level there are 1500 water supply systems. Most of them are protected with drinking water protection zones. A large number of water supply systems and special geological conditions in some parts of the country require extensive protection zones; consequently their total area amounts to approximately 20% of the Slovene territory. The protection zones before the adoption of new procedures described in the paper were defined and regulated in very different ways. Accession to European Union requires adoption of European legislation and gave Slovenia opportunity to establish new water management practice and strategies. Based on the implementation of the Water Framework Directive (Anonymous, 2000a) new Water Law (Anonymous, 2002) was passed in the parliament and the Ministry of the Environment and Spatial Planning later issued new drinking water protection regulations. The paper presents the present state of the art and strategies of Slovene drinking water protection zones.

General settings

Drinking water supply in Slovenia is mainly based on groundwater. The official data show that 90 to 95% of the total drinking water supply is provided from groundwater resources. Water is supplied from public systems to 85 % of inhabitants, private wells cover 6 % and rain water reservoirs 5 %. The remaining 4 % are supplied from other sources, mainly by means of direct surface water abstraction. 47 % of the total drinking water supply is used for households, industrial use represents 39 %, agriculture 8%, tourism 5 % and other applications 1 %. In spite of water abundances, some shortages are present in south-western, south-eastern and eastern parts of the country. These deficiency areas cover 28 % of the total area and are represented by 15 % of the total population. Public water supply is still not available in 587 settlements; all of them have less than 2 000 inhabitants. (Horvat & Ivartnik, 2004, Hočevar Grom et al., 2005)

Throughout the country substantial differences in relief exist, consequently rainfall varies considerably. Average yearly rainfall at high altitudes is above 3000 mm/year, while in areas with continental climate the average rainfall is about 800 mm/year. For the period 1961–1990 average rainfall in Slovenia was estimated to be 1567 mm/ /year, evapotranspiration 650 mm/year and runoff 917 mm/year. The latter represents a discharge of 588 m^3/s. (Kolbezen & Pristov, 1998).

The geology is strongly influenced by the contact between Adria and Eurasian plates, the territory is dissected by numerous faults and napes. Rocks are predominantly carbonates of Mesozoic age, rocks from other ages are also present. Intergranular porous aquifers predominate in an area of 20273 km^2, covering 18 % of the country, occurring in the tectonic depressions and valleys in the central and north-eastern part of the country. These sediments are mainly gravels with sand. It is estimated that in total 18.8 m^3/s of dynamic groundwater are stored in these aquifers, providing major water resources for the population living in bigger cities. Karstic and fissured aquifers in limestone and dolomite rocks that are part of Dinaric karst cover about 62 % of the area. They mainly occur in the southern and western part of the country. It is estimated that these aquifers store in total

31.6 m^3/s of dynamic groundwater. For water supply, deep fissured aquifers in dolomite are very important. Another 20 % of the country is estimated as low permeable rocks and sediments. Groundwater is according to a very rough estimation represented as 8.5 % of the total outflow.

Past protection zone regulations

The oldest existing drinking water protection zone ordinance that is still in effect is from the year 1964. Only few ordinances were enacted before the end of the seventies. A more intensive period of passing water resource protection ordinances began after the methodology of Breznik (1976) had been published. This methodology was also included in the spatial planning documents, but only as a guideline. In the nineties two new methodologies for drinking water protection zones were prepared (Rismal, 1993; Veselič & Petauer, 1997). Again they were never implemented on legal grounds. A considerable number of ordinances were passed also in the mid-eighties, and there was a noticeable increase also after 1995. This fact is to a great extent in relation with the reorganisation of local government, which gives competence over water resource protection to local communities.

Soon after the majority of ordinances were enforced it was realised that many problems exist in the implementation of demands defined by them. Small local communities were able to protect their water resources only on their territories but were unable to agree on the protection measures on the grounds of neighbouring communities. It was realized that sometimes large parts of recharge areas remained unprotected. A comparative analysis of disposable ordinances shows also big differences among the ways of protection. (Brenčič, 2001) These differences would be acceptable in the case of different aquifer types in different parts of the country. However, also protection measures in areas with the same hydrogeological properties were found to be very diverse and dependent from the author of expert grounds for the protection of the resource and on the institution that passed a certain act. Protected areas with three zones prevail, followed by those divided into four zones.

After passing new Water Law (Anonymous, 2002) it was decided by Ministry of the Environment and Spatial Planning that due to the different practice drinking water protection zones for all types of water resources should be defined in one legislative rule and regulated by the government. Now drinking water protection is responsibility of the state, thus local communities and their public enterprises can be, based on the licence, responsible only for operating and managing the operation of waterworks.

Based on the obligations defined in Water Law (Anonymous, 2002) three new rules were enforced; *Rules on criteria for the designation of a water protection zone* (Anonymous, 2004a), *Rules on construction in water protection zones that may be carried out only pursuant to the water consent and on the required documentation for obtaining water consent* (Anonymous, 2004b) and *Regulation on the marking of the drinking water protection areas and bathing water areas* (Anonymous, 2004c). The regulations define criteria for the delineation of drinking water protection zones. They define also interdictions, limitations and measurements on drinking water protection zones.

Methodological approach

Starting points for determination of drinking water protection zones are defined according to several principles. These principles were developed on the basis of natural conditions and water supply management strategies of the supplied area. Natural conditions should be considered during the planning and designing of protection measures. Also protection from the pollution and other harmful loads must be included. With in situ methods or calculations the existing and plausible flow paths of pollutants and pathogenic organisms from the source to the abstraction zone must be investigated. Risk analysis must be performed for the activities in the recharge zone that represent a threat to chemical, quantitative or ecological status of water body. Together with its influence on local and regional development it is necessary to estimate the long-term significance of the water resource from the water management perspectives. It is also very important to estimate water accessibility. The cost of protection and water treatment is not among unimportant factors. Protection zones must be defined in a way that enables feasible measures and other arrangements for maintaining natural status of the water body. In the areas where present loads are too high, drinking water protection zones and measures implemented on them should minimize the risks.

General natural characteristics of groundwater and surface water resources are very well known and can be find elsewhere (e.g. Cechc, 2003; Domenico & Schwartz, 1990). However, stricter and sometimes very simplified definitions were introduced in the legal articles. For the understanding and implementation of valid legislation based on these definitions, the systematization of drinking water resources is important. For this purpose drinking water protection zones were divided into two main groups; into groundwater and surface water resources. These two groups were further divided into subgroups. Groundwater resources are divided into three subgroups: intergranular aquifers, karstic aquifers and fissured aquifers. Surface water resources are divided into flowing waters and stagnant waters. (Fig. 1.)

Water Law (Anonymous, 2002) defines groundwater and aquifer in the same way as Water Framework Directive (Anonymous, 2000a) Article 2. Groundwater means all water stored below the surface in the saturation zone and in direct contact with the ground or subsoil. Aquifer means a subsurface layer or layers of rock or other geologi-

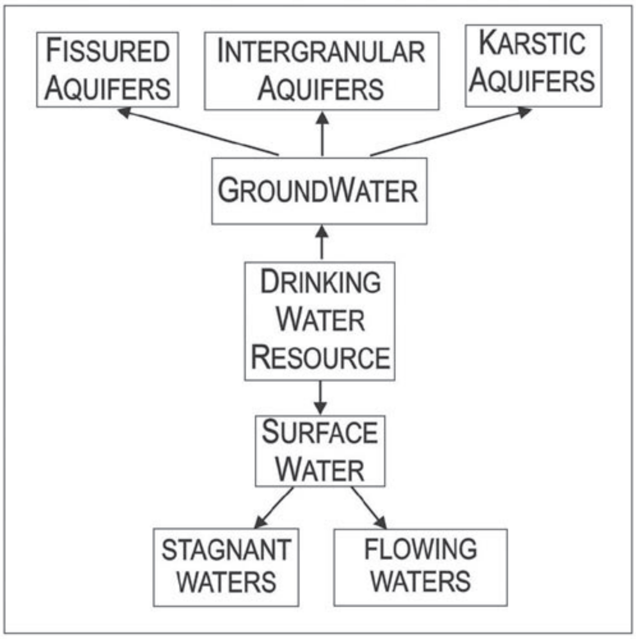

Figure 1. Diagram with the classification of drinking water resources

cal strata of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater.

Intergranular aquifer is a geological medium where porosity is a consequence of contact between grains in sediment or rock. Groundwater flow in this aquifer can be described with Darcy law and protection zones are defined from the calculations of isochrones based on it. Normal filtration velocity of groundwater in the aquifer is usually lower than 10 m/day and changes of meteorological conditions are reflected in the groundwater regime with a delay. Distribution of groundwater velocity through the aquifer is relatively homogenous. As a rule, risk for the aquifer pollution diminishes with the distance from the abstraction point. During the flow path in the aquifer pathogenic organisms usually die off.

Karstic aquifer is a geological medium where channel porosity prevails. Inside channels the longitudinal velocity of water in the aquifer is much higher than in the other parts of the aquifer. It is not possible to describe the groundwater flow with Darcy law; water velocity is usually much higher than 10 m/day. Distribution of groundwater flow velocity through the aquifer is very heterogeneous and as a consequence the risk for resource pollution does not depend on the distance from the abstraction zone. Retention and filtration characteristics of this aquifer type are weak. Conditions in the aquifer are strongly dependant on meteorological conditions. Turbidity of water is very often present, pathogenic organisms during groundwater flow through the aquifer do not die off. It is not possible to calculate isochrones of groundwater flow.

Fissured aquifer is a geological medium where the porosity of fissures and joints are predominant, intergranular and channel porosity my also be present. The groundwater flow can be laminar or turbulent. According to the flow characteristics this type of aquifer can be similar either to the intergranular aquifer or to the karstic aquifer. If field investigations confirm that the flow in the aquifer is laminar, then drinking water protection zones are defined according to the criteria for intergranular aquifer. Otherwise they are defined according to the criteria for karstic aquifers.

In accordance with Water Framework Directive (Anonymous, 2000a) Article 2 surface water is also defined. Surface water means inland waters except groundwater; transitional waters and coastal waters, except with respect to chemical status, according to which it shall also include territorial waters. Chemical, quantitative and ecological status of surface waters largely depends on seasonal meteorological conditions.

Flowing waters are defined as torrents, creeks and rivers regardless of whether they are perennial or permanent. The gradient of water surface greatly influences the flow velocity. This group includes also stagnant waters where longitudinal direction of water velocity is evident and the resident time in water body is less than 5 days.

Stagnant waters are waters with a very slow flow or totally stagnant where gradient is not present. By meteorological conditions the chemical and quantitative status of water body is heavily influenced.

Definition of protection zones

According to the water management strategy it was decided that for all resources a special zone around the abstraction point and three additional zones should be enforced. They are defined as abstraction, inner, middle and outer protection zone respectively. According to the final capacity of the waterworks system the area of the protection zones is defined. It should not be smaller than the natural recharge area. Water from the outer boundaries such as other aquifers and river channels or water flowing out from the protection zones should be also taken into consideration. If risk analysis shows the need for further special distribution of measures, inner protection zones can be further divided.

Abstraction zone should provide direct physical protection of all technical facilities for water abstraction and all accompanied facilities that are necessary for safe and reliable operation of water distribution on the site. This zone is intended to protect unauthorized access and to prevent the appearance of dangerous substances at abstraction point and in its near vicinity. Physical protection should be erected in all directions around the technical facilities. The zone should be property of the waterworks owner. Only maintenance and other activities intended for water supply operation can be performed in the zone. If abstraction is performed with a well or horizontal drainage, an area of 10 m around the object should be fenced. If the abstraction zone is represented by karstic spring the diameter of the enclosed area should not be less than 20 m. If some open fissures or karstic channels exist in very near vicinity and they are directly connected with the spring, they should be also enclosed. For surface water resources, the enclosed area on the bank is defined with a 20 m fenced belt. It must also be marked with buoys on the water surface. If the riverbed is narrower than 20 m, a 10 m wide bank on the other side should also be fenced in.

In the inner protection zone all provisions for pollution prevention from pathogenic organisms such as bacteria, viruses, parasites, larvae or any other pollution that could be fatal for water resources must be established. The limitations in this drinking water protection zone are very strict. This zone need not be established only in the case when drinking water is pumped out exclusively from a deep aquifer or if the aquifer is covered with a sufficiently thick cover layer of very low permeability.

In the middle protection zone sufficient retention time for the degradation and dilution of slowly decreasing pollutants should be provided. In this zone drinking water protection zone limitations are strict.

In general, the outer protection zone is defined as the total recharge zone of a water resource. It can also include areas outside of the recharge area where accidents can influence the chemical and quantitative status of the water resource. In this zone water must be protected from radioactive substances and from pollutants with slow degradation. In this drinking water protection zone limitations are moderate. The zone is intended to provide sanitary adequacy of drinking water.

Expert grounds

Planning and determination of drinking water protection zones must be performed on the basis of several items of information obtained from field investigations and information available from literature and other sources. Usually expert grounds prepared by a hydrogeologist or hydrologist given in a special document present the baseline for enacting the drinking water protection ordinance. Basic investigations for the delineation of protection zones consist of groundwater and hydrogeological maps based on field measurements and numerical models. Classical geological methods such as mapping of litostratigraphy and structural analysis can be applied. Geomorphological and surface catchment analysis of drainage network helps to delineate the recharge zone. Hydrogeochemistry and isotope analysis can be used as additional tools for the delineation of protection zones. Combinations of all these analyses are usually used in the preparation of expert grounds.

For karstic aquifers some additional investigations are needed, consisting mainly of tectonic analysis, tracing experiments and speleological investigations of caves and potholes in the recharge area. Determination of karstified zones inside of epikarst or phreatic zone of the aquifer where very fast water flow towards the source is present is the main goal of these investigations.

Groundwater protection zones

Criteria for intergranular aquifer protection zones are well established in literature (e.g. Matthes et al., 1985). They are defined according to the travel time isochrones in the aquifer. In our case, the inner protection zone boundary line is defined at 50days' travel time from any point below groundwater level to the well. The zone around the well should not be smaller than 50 m. Boundary line of the middle zone is defined at 400 days' travel time from any point below groundwater level to the well. (Fig. 2.) The area of this zone

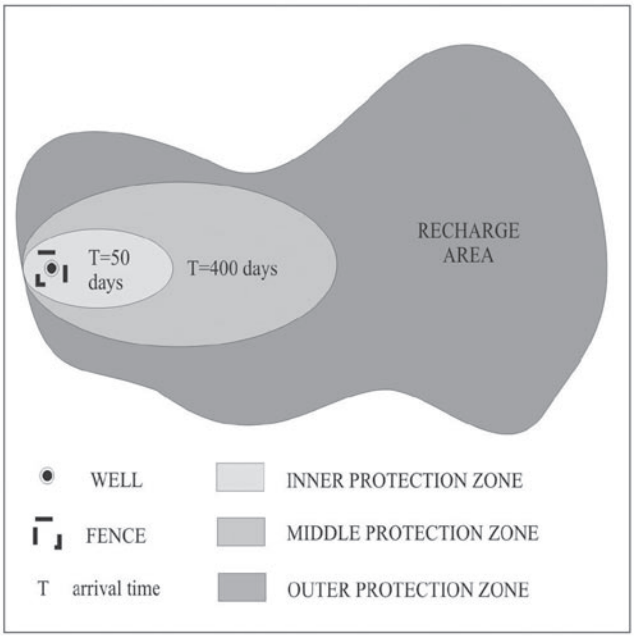

Figure 2. Protection zone on intergranular aquifer

should not be smaller than 25% of the abstracted water recharge area that is representative for average hydrological year. If the aquifer is covered with a continuous low-permeable layer with a thickness of 5 m or more, the boundary line of the middle protection zone can be shifted toward the direction of the well. It should not be closer than 1 km to the 50-day isochrone. Boundary line of the outer protection zone is defined with a depression cone or as the total recharge area. The dispersion of plausible pollutant toward the well on the borders should also be included into the definition of outer boundary line. If surface water is part of the recharge, its recharge area should also be included.

Karstic aquifers are among the most complicated aquifers. The groundwater regime very much depends on several factors. It is strongly connected with the level of geomorphological and tectonic history of the area. (European Commission, 1995) The criteria for karstic aquifers can not be defined in one manner, each aquifer requires a special approach. Proposed criteria for karstic aquifers should be treated as guidelines.

The inner protection zone of karstic aquifers is defined as the area where possible pollutant travels from the injection point to the abstraction zone less then 12 hours. With this zone all fissures, known channels, swallow holes, poljes and other karstified regions with direct connection to the source are included. The middle protection zone is defined as the area where possible pollutant's travel time is more than 12 hours. (Fig. 3) If the area of the inner or middle protection zone is covered with 8 m or more of low-permeable beds, the covered part is included into the zone with lower protection regime. The same applies to a perched aquifer, separated above with a low- permeable bed of 5 m or more. The outer protection zone is defined as the total recharge area; it is usually represented with non-karstified or low-karstified rocks.

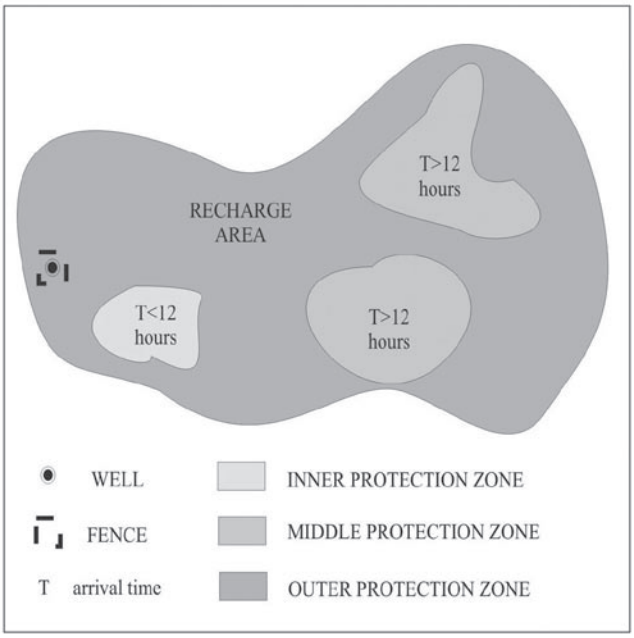

Figure 3. Protection zone on karstic aquifer

Surface water protection zones

Surface drinking water resources, especially larger ones, are much more prone to pollution than groundwater resources. Effects of upstream pollution on the abstraction are very fast, usually more severe than in the case of groundwater. Due to the fast spreading velocity of the pollution available intervention times are shorter than in the case of aquifer pollution. This is the reason why the definition of surface water protection zones is more complicated and less agreement can be found in the practice on the method for their determination.

It was decided that for the delineation of drinking water protection zones on surface water bodies three methods can be used; (1) method of distances, (2) method of isochrones and dilution and (3) method of intervention times. Methods are the same for all subgroups of surface water. They are defined hierarchically, from the easiest method of distances to the most pretentious method of intervention times. The most conservative is the method of distances. By this method of protection zone determination only the implementation of prescribed distance along the watercourse is required. More data are needed for the other two methods. They should be combined also with active protection measures. The method of intervention time demands active surveillance of the protection zone. The benefit of the latter is less space required for the zones. For all three methods the area at the water level of flood with the return period of 100 years is defined. The inner and middle protection zone on both sides of the bank must include the belt of 100 m. In all cases the outer protection zone is defined as the total recharge area.

Method of distances defines inner protection zone within a distance of 15 000 m in the upstream direction and 50 m in the downstream direction for the flowing surface water (Figs. 4 and 5). Mid-

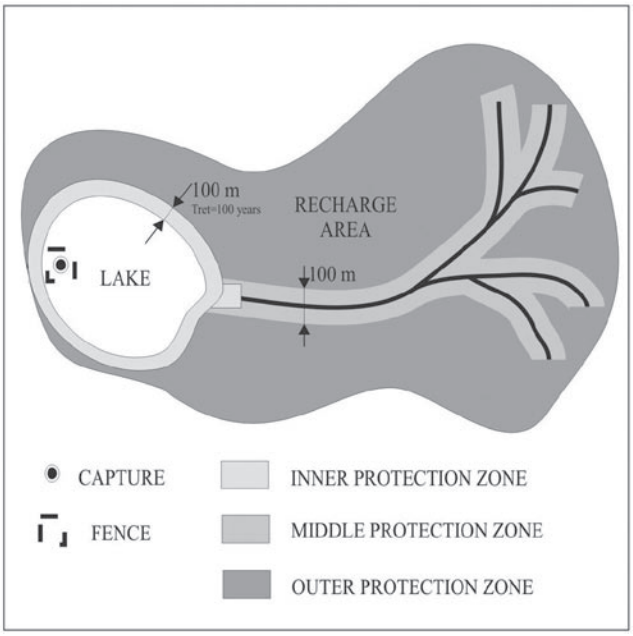

Figure 4. Protection zone on flowing water body

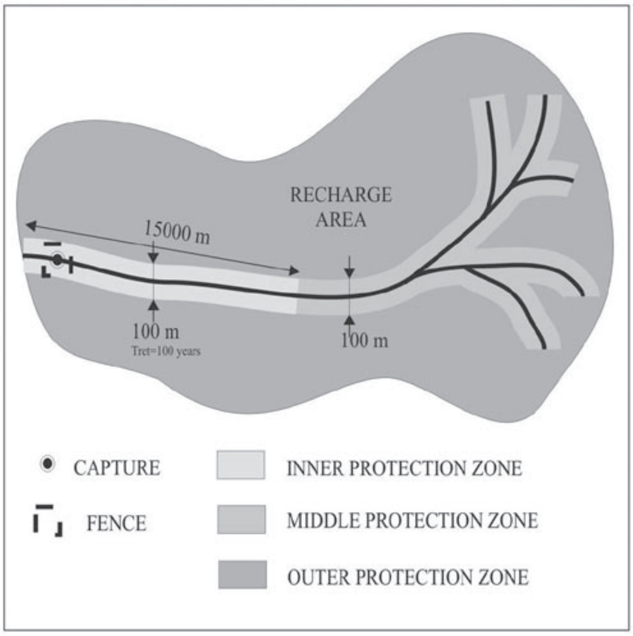

Figure 5. Protection zone on stagnant water body

dle protection zone must consist of all river or creek channels in the recharge area. Inner protection zone for stagnant waters includes all stagnant waters. Middle protection zone includes all flowing recharges.

Method of isochrones and dilution defines inner protection zone for the flowing surface water as isochrone of 1day's arrival time. Middle protection zone is defined with the arrival time of 5 days. For stagnant waters inner protection zone is defined with the isochrone of 10 days' arrival time and middle zone with an arrival time of 20 days.

The intervention method defines the protection zone for flowing waters with the isochrone of 4 hours. This zone should not be shorter than 500 m. The middle zone is defined with the isochrone of 12 hours. Inner protection zone for stagnant waters is defined with the isochrone of 12 hours and middle zone with 48-hour isochrone.

Some special cases of drinking water resources are also considered. They include a combination of different aquifers, recharge of aquifer through surface water, artificial recharge and abstraction that represents a combination of surface and groundwater. For those resources protection zone delineation criteria are combined in a similar way as the combination of criteria for groundwater and surface water.

Discussion

Criteria for the delineation of protection zones present a firm basis for spatial planning and management in the recharge areas of drinking water resources. Only criteria are not sufficient for proper protection. It is necessary to define activities that are acceptable or prohibited on drinking water protection zones. They are usually laid down with interdictions, limitations and measures. By interdictions some activities are completely banned, repository of radioactive materials on drinking water protection zones is a good example of such activities. Measures are usually in the form of constructions that are built for the drinking water protection purpose, e.g. fences raised to prevent cars run away from roads. Limitations are defined with the intention to limit some practices on drinking water protection zones. Very well known among them are limitations to certain agricultural procedures, such as the spreading of manure and fertiliser.

The nature of allowable activities and interdictions was defined in advance during past drinking water protection practice and ordinances. All of them were prescribed in the particular regulation by some articles and changes to them during the proceeding for construction licence, even if it could be proved that the activity represents no harm to water, were nearly impossible. Due to different nature of water resources not all consequences of activities performed in the area of drinking water protection zones could be predicted correctly in the general expert judgment that was included in the expert grounds for the ordinances preparation. The technology of water protection also develops with time and something that was harmful to water in the past today represents no risk or vice versa. Consequently, more open approach to interdictions, limitations and measures was adopted with new regulations for drinking water protection zones. In spite of this some activities are still banned on the protection zones.

Interdictions, limitations and measures enforced were determined based on expert judgments of existing construction and standard activity classifications. Together with prohibited or unconditionally allowed activities some conditionally allowable activities were also defined. They can only be implemented on the area of drinking water protection zone when no impact on drinking water resource has been found by risk analysis. Risk analysis is defined by the same legislation as criteria for drinking water protection zones. The legislation prescribes the content of risk analysis and presents criteria for risk determination. Risk analysis is defined based on the methods of water flow modelling and pollutant transport calculations. Together with the estimation of the risk represented by construction or particular activity performed on the area, risk analysis is important also as an optimization tool for technical protection measures.

Risk analysis that is defined by drinking water protection zone legislation is not only important for the protection of particular water resource, it represents also a good starting point for the implementation of Member States water bodies protection required by Water Framework Directive (Anonymous, 2000a). The Directive requires protection of water bodies as a whole and not only from the point of particular activities or buildings that can influence drinking water resource with their pollution load. Risk as well as probabilities must be estimated for discharges, emissions and losses of the substances harmful to water. Methodology of risk analysis prescribed on drinking water protection zones applies for such estimations.

Conclusions

Safe and reliable drinking water presents a firm basis for healthy everyday life. Drinking water protection zones are important parts for safe drinking water supply. They introduce interdictions, limitations and measures into human environment. They are very important in providing higher and natural water status of water bodies. At the same time these restrictions cause several spatial conflicts, such as different interests during spatial planning, management and land use. Up to the present, drinking water protection zones delineation restrictions have been defined only generically, mainly as inhibitions or permissions. With the integrated approach to all drinking water protection zones described in the paper, a uniform standard for recharge zone of drinking water protection is given. On the basis of impact assessment and risk analysis of activities that take place on the surface of protection zones according to these standard procedures are developed that enable these activities. Procedures of this kind are included in the drinking water zones delineation. They are very important during the process of acquiring the documentation required for obtaining water consent according to the Water Law (Anonymous, 2002). It is expected also that with the unified approach to all drinking water protection zones an additional step toward good water status required by the Water Framework Directive (Anonymous, 2000a) will be achieved and some present practices that are detrimental to water resources will be changed.

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References

Anonymous, 2000a: Directive 2000/60/EC establishing a framework for Community action in the field of water policy.

Anonymous, 2002: Water Law. Official Gazette of the RS 67/00.

Anonymous, 2004a: Rules on criteria for the designation of a water protection zone. Official Gazette of the RS, 62/04.

Anonymous, 2004b: Rules on construction in water protection zones that may be carried out only pursuant to the water consent and on the required documentation for obtaining water consent. Official Gazette of the RS 64/04.

Anonymous, 2004c: Regulation on the marking of the drinking water protection areas and bathing water areas. Official Gazette of the RS 88/04.

Brenčič, M. 2001: Analysis of standardized measures for the protection of drinking water resources from negative impacts of roads. Acta hydrotechnica (Ljubljana) 19/31: 137-153.

Breznik, M. 1976: Methodology for drinking groundwater protection and protection areas and zones determination. In: Regionalni prostorski plan za območje SR Slovenije, Zasnove uporabe prostora – vodno gospodarstvo. Socialistična republika Slovenije, Zavod SR Slovenije za družbeno planiranje, Področje za prostorsko planiranje (Ljubljana): 119-176.

Cechc, T.V. 2003: Principles of Water Resources – History, Development, Management and Policy. John Wiley & Sons: 1-446.

Domenico, P.A. & Schwartz, F.W. 1990: Physical and Chemical Hydrogeology. John Wiley & Sons: 1-824.

European Commission, 1995: COST action 65 – Hydrogeological Aspects of Groundwater Protection in Karstic Areas; Final report. Directorate General – Science, Research and Development: 1-446.

Hočevar Grom, A., Petrovič, A., Gale, I., Hojs, A. & Štern, I. 2005: Drinking Water Monitoring 2004 – Report on Drinking Water in Slovenia. Center za zdravstveno ekologijo (Ljubljana): 1-57.

Horvat, M. & Ivartnik, M. 2004: Drinking Water Supply in Slovenia – 2003. Inštitut za varovanje zdravja RS (Ljubljana): 1-50.

Kolbezen, M. & Pristov, J. 1998: Surface Streams and Water Balance of Slovenia. Ministrstvo za okolje in prostor, Hidrometeorološki zavod Republike Slovenije (Ljubljana): 1-98.

Matthess, G., Foster, S.S.D. & Skinner, A.C. 1985: Theoretical Background, Hydrogeology and Practice of Groundwater Protection Zones. Verlag Heinz Heise (Hannover) 6: 1-204.

Rismal, M. 1993: Groundwater Protection – Guidelines for Preparation of Legislation for Groundwater Quality Protection. Inštitut za zdravstveno hidrotehniko (Ljubljana): 1-69.

Veselič, M. & Petauer, D. 1997: Methodology for Groundwater Protection Zones Determination. IRGO, GEOKO (Ljubljana): 1-13.