

Protection of the karst aquifers in the river Kupa catchment area and sustainable development

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Abstract: River Kupa catchment area is one of the most significant water resources in Croatia, located in the border area with Slovenia. About 85 % of total amount of water of the river Kupa discharges on the Croatian side so the catchment areas are of the significant dimensions. It is the typical karst aquifers of Dinarides, with relative fast water exchange in the ground, with high velocities of groundwater flow, opened towards the surface by numerous swallow holes, therefore the aquifer of high vulnerability and high risk. High quantities of high quality springs water (about 3.5 m³/s) give the strategic importance to the whole area, and the water resources get the high strategic importance of future development of the west part of the Republic of Croatia. In this paper the investigation results of the whole water system on Croatian side are presented. Thereby, the available investigation methods were used; from the classical hydrogeological approach, the detail hydrologic calculation of water balance, the groundwater tracing, hydrogeochemical analyses and modelling and finally the protection zones and protection measures for the whole area. It is emphasized that the catchment areas lie in the zones of major traffic corridors, oil pipelines, railway and numerous settlements with developed wood industry and all of those subjects, with prevention measures and remediation activities, should satisfy very strict protection requirements for the karst aquifers. Although they are the karst aquifers of high risk, the solutions exist, even the possibilities for lowering the existing risk from today's development level of the whole area.

Keywords: Kupa river catchment area, karst springs, protection system, groundwater, hydrogeology.

INTRODUCTION

Karst aquifers recently in the public water supply get the growing importance in the Europe, especially in Mediterranean and Alps regions, where on many places presents the only source of potable waters. Value in the water supply grows foremost because of the high quality of water and the position of the majority karst catchments in relatively weak developed mountain areas of very short loaded space.

Croatia has significant high quality water resources in the karst area of Dinarides, from which the whole Adriatic coast and numerous towns and settlements in continental area have organized the water supplying systems. The special place by this has the water resources in the catchment of Kupa River, which flows through borderland between the Croatia and Slovenia. The largest part of the huge karst springs, and main river spring has been placed on the Croatian side. The catchments extend deep in the area of Gorski Kotar, and protection problems mainly are bound the management system on the Croatian side.

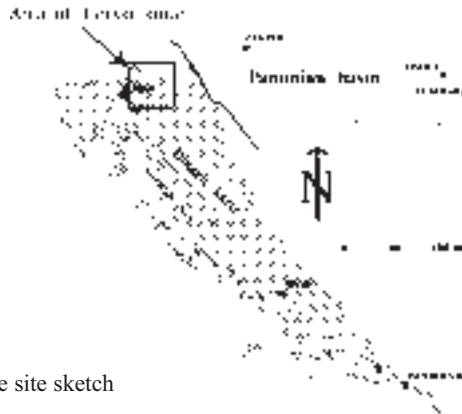


Figure 1. The site sketch

Importantly emphasizes that the area of the catchment of Kupa river is also the singular possible traffic corridor between Zagreb and the greatest Croatian harbour Rijeka on the Northern Adriatic. Consequently, on one-hand stands the important water resources, and per contra all more expressed loads of area, what absolutely weeds to be synchronized on principal of sustainable development.

THE GEOLOGIC DESCRIPTION

Gorski Kotar is in the geologic point of view very complex area, so hydrogeological analyses are complex, too. Gorski Kotar is the typical karst area mostly built from carbonate rocks in different lithostratigraphic levels. The oldest are clastic layers of Carbonous ages at the core of anticline form of Dinarides. Has been confirmed sedimented the clastics of Permian ages with appearance of baryte and dolomites. In the Triassic have known the continental phases, and also the continuity sedimentation in upper Triassic, which begin by clastics and finished with the series so called "main dolomites". Transfer from Triassic to Jurassic period has been marked with the appearance of limestones and gradual predomination of limestones above dolomites. Has been represented the whole Jurassic with different varieties of dolomite component in the end of period as the youngest layer. From Quaternary layers in the mountain region prevail fluvioglacial sediments like ruminants of glacier activity, along Kupa river alluvial deposits and debris on steep slopes of canyon.

Upper part of the Kupa river catchment is of very complex tectonic structure. The base is the anticline form, which raises the oldest layers on the surface (Carbon), however has been proved the existing of overthrust structures in Gorski Kotar region.

THE HYDROGEOLOGIC DESCRIPTION

Gorski Kotar is the area with precipitations, which on the mountain chain along the Adriatic coast riches up to 4000 mm yearly, and gradually diminish inland. Average yearly air temperature is the adequate to continental climate and in the mountain area is about 6 °C and inland slowly increases. However, influence of Mediterranean expresses, so and area of Gorski Kotar has very irregular yearly distribution of precipitation with long summer dry periods and large concentration throughout the autumn, winter and spring.

Gorski Kotar is the typical karst area of Dinarides, in which it is possible to stand out 4 groups of rock of the different hydrogeological characteristics, which with their position in the geologic structure dictate the frame of drainage systems, directions of groundwater flows, position of the karst springs and intrinsic dynamics of karst aquifers. What is in the Gorski Kotar complicate in hydrogeological point of view is very irregular interrelationship of the rocks of different permeability in very complex geologic structure in the subduction zone between African and European plates. Rifting, tumbling and tangential movement in the combination with neotectonic moving very often bring the younger high permeable carbonate rocks in the base of the older impermeable complexes, so the groundwater flows below the older impermeable rock sometimes creates the bewildered hydrogeological picture. Core anticline form of Gorski Kotar is built by impermeable clastic layers of Palaeozoic ages, what is significantly for the forming of the divide between Adriatic and Black Sea catchment areas. Gorski Kotar as a whole belongs to Black Sea catchment, and the karst drainage area of size about 1000 km² on the Croatian is drained towards the river Kupa and its tributary Čabranka, which from the heart of the mountain areas of Gorski Kotar by deep canyon get through towards the Panonian basin and river Sava. River Kupa starts with numerous strong karst springs, whose yearly outflow varies between 6 and 507 m³/s. Due to very complex geologic structure, there are some differences in natural characteristics of spring water, from the temperature, through the groundwater residence time and chemical structure of water, which express the dimensions and extending of the catchments for single groups of karst springs. Quality of spring water is dependent on the loads in particular parts of the catchments too, and can be the indicator of the distribution of influential areas.

The hydrogeological interpretation of the catchment of discharge zone of Kupa river has been worked on the basis of the hydrogeological map, numerous tracing tests, hydrogeochemical analyses and water balance calculations for defined drainage systems inside the catchment of Kupa river. It was defined the following catchments: catchment of Čabranka spring, catchment of Zamost spring, catchment of Kupa spring, catchment of Lokvarka river, catchment of Velika and Mala Belica springs and catchment of Kupica and Zeleni Vir springs.

The catchments of Kupa river spring zone on Slovenian side is not hydrogeological treated in this paper, but the hydrological analysis show that the water contribution from Slovenian side is only about 10-12 %, because the catchment in Slovenia stretches downstream from Brod na Kupu.

Importantly emphasizes that the predominant role in the described hydrosystem has Kupa river, and its left tributary Čabranka river, which together creates common drainage system taking away water towards Black Sea catchment, which are infiltrated in karst underground on the surface of about 1000 km². The flow rate on the location of exit profile in Brod na Kupu is in average 40,9 m³/s, minimal 6,0 m³/s and maximal 507 m³/s, whereof: Catchment of Čabranka river (9,08 %), Catchment of Kupa springs (32,70 %), Catchment of Velika and Mala Belica springs (13,98 %), Catchment of Kupica and Zeleni Vir springs (19,15 %), Surface inflow (13,09 %) and estimated inflow from Slovenian side (12 %).

HOW TO MANAGE WATER RESOURCES OF THE KUPA RIVER IN THE SUSTAINABLE DEVELOPMENT CIRCUMSTANCES

Water resources management means the management of whole natural system, what in the case of Kupa river includes the common activity of Croatia and Slovenia, because the catchment extends in two states, and according to European Union Water Directives for the water

resources management catchment is the basic unit. Aside from this the Kupa river catchment is the part of Danube river unit, so consequently enters in the circle of integral management of Danube system. However, there are things, which Croatia can and must independently work on, and this is the efficient protection of karst aquifers on its territory and certain engineering activities within these protections. The basic task of this paper is to present foremost natural characteristics of the part of Kupa river catchment in the Croatia, activities on protection of water resources on a national scale, and what is the most important to stimulate common project, the first research, and then management system of this significant water resource on the international level.

Water resource protection system for the Kupa river catchment area in Croatia was prepared due to the Regulation for the protection of potable water in Croatia, which for the karst aquifers has been made on the basis of European experiences through projects European Union COSTS 65, 620 and 621 and own experiences in the karst of Dinarides. Criteria for the defining of protective zones has been bound the combination of time of transport and apparent flow velocities, in other words on the dynamics in the saturated part of karst aquifers, and vulnerability and risk mapping what is recommended for the detail research of the highest vulnerable areas (BIONDIĆ ET AL., 1998). The special attention has dedicated to the function of covering layers, what can reduce the high level protected parts of the catchments. For the Kupa river protective system has been made towards described subcatchments and occupies great part of the area of Gorski Kotar. However, it is important to point out that the use of selective approach with different protection levels which depend upon natural conditions in the combination with engineering holds in the space enable the development and normal proceeding of life in sustainable conditions. Completely is clear that in these spaces need the exceptional attention will turn to where and how to locate and construct the different type of objects without which is impossible to insure the necessary development of the country. By this is needed to distinguish two basic levels. First is surely local, how to organize the life, where and which industrial contents inputs the space, and the special attention needs to be directed on wastewater and communal and industrial landfills. The other level is at least also significant, and these are important infrastructure objects, what are in case of Kupa river catchment important road directions, fast railway, gas line etc. There are so much essential contents through relative narrow and naturally high vulnerable area.

In conclusion it is necessary to point out that the Kupa river catchment on Croatian side is rich with high quality water, which today get the level of strategic resources for future development of the country. Problem of the seasonal irregular distribution of the precipitations will be possible to solve the first with proper management, but in combination with engineering activities, because the present minimal flow rates of Kupa river basin not enable the optimal use of this natural resource. Especially important will be definition of the level of sustainable flow rate, what is for sure the question of common approach and management for this water resource from both sides, Croatia and Slovenia.

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