Management of transboundary karst groundwater resources

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A b s t r a c t

Karst represents a specific area consisting of surface relief and a surface-underground hydrographical network resulting from the water circulation and its aggressive chemical and physical action in cracks, joints and fractures along the layers of soluble rocks, such as limestone, chalk and dolomite as well as gypsum and salt. Karst is characterised by soluble rocks located near or at the surface. The karstification process results from the physical and chemical water action on the solution and transportation of elements from the rocks. Over time, the permeability of the rock mass is greatly enhanced, and rainwater, instead of being mostly diverted over the surface and into open stream flows may be infiltrated. Thus, karst terrains are characterised by a high proportion of underground drainage. A soluble rock formation may contain voids with a spectrum of sizes from submicroscopic cracks (10^{-3} mm) to caverns tens of meters across.
Karstified rocks can be found in all parts of the world. In certain regions they are quite frequent and cover wide and deep areas (e.g. France, Switzerland, China, Turkey, Cuba, Greece, Slovenia, Croatia, Bosnia-Herzegovina, Kentucky State of USA etc.), whereas in other regions they are rare and appear only in certain areas most often as shallow surface karst (some countries of northern Europe and South America). Karst is estimated to cover 20 to 25 % of the surface of all continents. Karst regions provide water supplies for up to a quarter of the world's population.
The world population growth has resulted in many karst areas becoming densely populated. This fact has caused an increased interest in theoretical and practical research. Here we shall give several present methods of investigation and measurement in the karst, which can be carried out to gather the necessary data and to plan further activities. It should be noted that these methods could hardly be classified as strictly belonging to specific scientific disciplines. In essence they belong, in terms both of their use and their results, to various specialities.

Karstic terrains are highly sensitive and vulnerable to imposed stress. Karst usually lacks resilience in the face of such stresses, in this instance those generated by human processes. The response of karst waters to such processes is highly distinctive and sets the karst environment apart from other terrains irrespective of location or geologic type. Karst groundwater vulnerability depends on aquifer infiltration conditions, as well as on the spatial and temporal distribution of hydraulic conductivity and strong coefficients. Wells and springs in karst regions, in principle, are very vulnerable. They should be protected carefully based on very special and individually oriented monitoring.
For water circulation in karst the determination of the catchment boundaries and the catchment area, which is starting point in all theoretical and engineering analysis, presents extremely complex, sometimes not easily solved tasks. The catchment areas in karst vary according to change of groundwater levels. An amplitude of groundwater level oscillations often exceeds several hundred meters causing intercatchment overflow during high waters.
Due to the influence of karst, parts of many state boundaries (for example between France and Switzerland, France and Spain, Croatia and Slovenia, Slovenia and Italy, Croatia and Bosnia-Herzegovina, etc.) contain numerous hardly explored under-ground flows and aquifers. In this paper same examples of transboundary groundwater resources management from the Dinaric karst region will be given. The Dinaric karst, situated along the east Adriatic coast, is particularly well developed and deep, with very specific karst geomorphologic forms. In the past the necessity of investigating the water circulation in the Dinaric karst was caused by the fact that men have continually inhabited these

areas. While in other parts of the world the karst regions are mostly unpopulated or rarely populated, some parts of the Dinaric karst are densely populated. The needs of people living in those areas have brought about the development of theoretical and practical solutions in karst water exploitation and management. With the increase in the number of inhabitants in the surface of Earth, the karst areas will become more densely populated. Thus, the interest in the study of a broad spectrum of karstology will increase, especially with regard to water circulation, its phenomena, quantity, quality, exploitation and management. Due to its karstic characteristics the Cetina River catchment is partially in Bosnia - Herzegovina and partially in Croatia. Its groundwater flows from Bosnia - Herzegovina to Croatia. Moreover, a hydroenergetic system has been built through which along tunnel and pipelines water is taken away from the Buško Blato reservoir in Bosnia - Herzegovina into Croatia. Similar, although more complex situation is with water from the Trebišnjica River catchment. There are some ideas and plans to build new hydrotechnical system for transboundary karst groundwater exploitation and management but only in one country. Those and many others facts complicate the transboundary water resources management among neighboring states.

All previously elaborated facts point to the necessity of the existence and development of international co-operation within countries shearing karst underground resources. Without co-operation it has not been possible to monitor processes and co-ordinate actions. Its importance in the coming and probably critical period will significantly increase. Obviously a new approach for its practical realisation should be established because existing ones are insufficiently co-ordinated and therefore too expensive and inadequate.

International co-operation should help: (1) Strengthening institutional capacities; (2) Revising and completing national and international legislation according to water resources and environmental rights and principles; (3) Reducing pollution; (4) Mitigating consequences of floods and droughts, (5) Preserving biodiversity; (6) Promoting market economy instruments that take care of environmental protection; (7) Realising technologies that prevent or control pollution; (8) Reconsidering environmental quality standards and (9) Making water resources management in transboundary karst regions more efficient.

In the quest for sustainability, it is recognized that clear definitions are needed and that indices can and should be identified by which the concept can be monitored. The Bellgio Principles, for example, enumerated ten desirable characteristic of sustainability monitoring programs.

These demands are very complex and can only be accomplished if in all phases of problem solving the principles of comprehensive and integrity are regarded.