Past and present experiences of highways construction in Slovenia – groundwater and highways interaction

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Abstract: The article brings an overview of the experiences with groundwater problems during highway construction in Slovenia. Within the frames of three thematic groups, we show briefly the interaction between a highway and groundwater. Each thematic group is represented by a short methodological overview.

Key words: groundwater protection, groundwater management, urban groundwater, highways

Introduction

Road construction and operation is a specific activity that affects the environment. Because of emissions from traffic and the possibility of hazardous spills, roads present a risk to groundwater. Among several non-point pollution sources, roads present serious threat to drinking water supplied from groundwater, and water resource protection from the negative influences from roads should be approached with great care.

Vehicles are both direct and indirect source of pollutants on roads. As direct source vehicles contribute pollutants from normal operation and frictional parts wear. Indirect pollutants are solids that are acquired by the vehicle for later deposition. (Barrett et al., 1995) The runoff from daily traffic on roads can be a source of heavy metals (e.g., Pb, Zn, Fe, Cd, Cu, Cr, Ni), oil and grease, organic toxic compounds, particulate matter, nutrients (e.g. N, P) and other materials deposited on road surface. In an incident pollution, various chemicals can be spilled off, and it is impossible to predict the type of the pollutant.

In Slovenia, large highway construction works have been in progress since 1994. The highways cross numerous groundwater catchment areas, which calls for great caution during the construction and operation of highways. Several important questions about groundwater protection from highway runoff arose and various efforts have been made during the planning and construction stage to protect groundwater resources. Parallel to highways construction, several local roads are being reconstructed or totally rebuilt and these works also greatly influence the environment.

Since Slovenia is very reach with groundwater, aquifers are the main source of drinking water, and consequently drinking water supply from surface water represents only a small portion of the entire water supply. This abundance of water has its impact also on road construction. A lot of attention should be focused on the protection of water from impacts of roads as well as on the protection of roads from the impacts of water. This leads to the

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necessity for the involvement of hydrogeology into the design and construction of roads. During the construction of highways in Slovenia hydrogeology has played an important role, especially during the investigation period when basis for highway routing and planning were performed. During the construction period itself hydrogeology was involved mainly in bigger geological engineering works, such as tunnelling and deep cuts. During the operation hydrogeology is involved mainly in monitoring and sometimes in reconstruction works when due to complicated geotechnical conditions some constructions must be redesigned or repaired.

ROLE OF HYDROGEOLOGY IN PLANNING AND CONSTRUCTION OF HIGHWAYS

In Slovenia, the aquifers of intergranular porosity are the most important for water supply. They build 22 % of the country, and they are positioned in the tectonic depressions and valleys in the central and northeastern part of the country. They represent major water resources for the population living in bigger cities. Karst aquifers in limestone rocks are also very important. They build 32 % of the area and are mainly present in the southern and western part of the country. The characteristics of the aquifers with fissure porosity are very similar to those of the karst aquifers and cover about 15% of the area. Double porosity rocks cover 11% of the area. The rocks that can be classified as low permeable build 20 % of the country. (BRENČIČ ET AL., 2001).

On the average 41 % of all state roads cross intergranular aquifers. From the total length of highways, 51 % are positioned on intergranular aquifers, 22 % on karst aquifers, 10 % on fissured porosity aquifers, 9 % on double porosity aquifers and 8 % on low permeable rocks. (BRENČIČ & RIKANOVIČ, 2002). From these data it can be seen that in Slovenia highways seriously interact with important aquifers.

The relation between roads and groundwater is usually very diverse and complex. To classify and conceptualise the relation between groundwater and highways three groups of problems important for hydrogeological investigations can be determined:

a) Groundwater protection from highway influences
b) Protection of highway space from groundwater
c) Economic use of groundwater for highway operation.

Groundwater protection from highway influences is performed according to the legislation demands and characteristics of water resource that must be protected. In the Slovene legislation, the Water Act and the Environmental Protection Act require the protection of groundwater resources. The existing primary legislation is very general about the requirements for groundwater protection from road traffic influences. The measures for the protection of groundwater resources from the influences from roads are determined by regulations and governmental ordinances and more precisely by local drinking water resource protection acts.

A number of drinking water resource protection acts define restrictions and prohibitions of road construction. These restrictions are defined very diversely and refer to different categories of roads. A greater part of the ordinances includes prohibition of building a certain

road type in the inner protected zone. In some cases where road construction is prohibited, exceptions are permitted. Those exceptions are permitted in accordance with spatial planning documents and regulations, taking into account preliminary regulations about groundwater protection. Measures for groundwater protection in outer protected areas are of a more general nature, prescribing road construction to prevent groundwater pollution. Some more recently passed acts demand that newly constructed and reconstructed roads have a groundwater protection scheme and other projects dealing with road construction and maintenance. An important measure for the protection of water resources from negative impacts from roads are also technical engineering measures.

Hydrogeological basis for groundwater protection from the influences of highways is defined with the classification procedure that divides a highway route into various categories determined as water resources sensitivity model. The model is based on the simple conceptual model of the aquifer, which consists of an unsaturated and saturated part. In the model the estimation of transit time of probable pollutant through unsaturated and saturated zone is estimated. Together with the direction of groundwater flow in the model the source of the pollutant and pollution connected with the activities on the highway and around it were considered. The spreading velocity of the pollutant through the unsaturated and saturated zone was described with two parameters. To each parameter five levels are assigned. Vertical seepage of a pollutant in the unsaturated zone is described with the specific vulnerability parameter. The higher the velocity of vertical transport, the higher is vulnerability of the water resource. The horizontal seepage of the pollutant in the saturated zone is described with the exposure parameter. On the basis of the estimation of the probable pollutant spreading and progression into the direction of water resource the classification of arrival times from the spill off location or permanent pollution point to the water resource are classified. Based on the cross-classification, the combination of both parameters produces the estimation of the sensitivity of a water resource crossed with a highway. The estimation of the sensitivity of the water resources represents the guidelines for the selection of suitable technical protection measures divided into groups of sealing measures, sewage and dewatering systems. (Ajdič et al., 1999; Brenčič et al., 2001)

Protection of highway environment from groundwater is needed when a highway is constructed bellow the groundwater table. These problems can be defined as classical dewatering problems in deep cuts, trenches, galleries and tunnels. Sudden appearance of groundwater during the construction can seriously raise expenditures and in the worst case causes the loss of material goods and human lives. Therefore, strong emphasize is given to the prediction of possible inflows or inrushes into the excavations during planning stage. In the areas prone to groundwater appearance hydrogeological investigations play an important role as a part of geotechnical investigations. The first stage of hydrogeological research consists of regional characterization that shows main groundwater flow directions in the area and the position of highway and its objects according to the groundwater flow. In the next stage quantitative hydrogeological conditions are defined (e.g., permeability of formation). On the basis of these measurements predictions about quantity and the nature of inflow are calculated. In the case when higher groundwater inflows are expected hydrogeologist purpose the solutions for groundwater dewatering and this is included into the construction plan.

Hydrogeological conditions in Slovenia are complex and diverse and due to these reasons some uncertainties in the characterization of groundwater conditions remain during the hydrogeological predictions. Hydrogeological prognosis should be considered as general recommendations under the frame of which proper technical measures must be established and defined. These technical measures must be planned as procedures open for corrections during the construction. Experiences show that hydrogeological predictions are not problematic in the environment of higher permeability. They are problematic in the environment of lower permeability where it is difficult to predict groundwater heads.
Due to relatively well developed water work systems in Slovenia, the economic use of groundwater for highway operation is to be an exception. In some highway routes, groundwater is captured as fire protection reserve in tunnels. At the very beginning of Slovenian highway construction in mid 1990's the possibility to use groundwater as an independent source for water supply of some toll and maintenance stations was considered. The idea was later abandoned do to the public benefit with the construction of some local water works.

CONCLUSIONS

Due to the prevailing part of groundwater in the drinking water supply of Slovenia, groundwater protection from highways influences plays an important role in the planning and construction stage of highways. During all phases of highway construction and operation, the influence of groundwater on the road body and its vicinity is very important and sometimes represents a great economical and constructional constraint. It can therefore be seen that groundwater plays an important role as a part of highway lifecycle.

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