The regime of inflow and runoff from Vrana Lake and the risk of permanent water pollution

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Abstract: Vrana Lake on the Cres Island (Croatia) is a specific natural phenomenon of 220 million m^3 of fresh water on the island's karst. Cres is small island with the total area of only 405,78 km^2 and the lake is only 2 to 3 km away from the island's coast. The Lake is kryptodepression, which has neither directly measurable inflow nor runoff. It is functioning as balance relation between salt and fresh water in karst aquifer. The dynamic of water exchange besides through lakes surface is happening through its underground aquifer also. The Lake is the only source of water supply for islands Cres and Lošinj.
Because of the noticed trend of declining of the water level at the end of eighties, complex hydrological, hydrogeological, hydrochemical, limnological and ichtiological researches started. Main goal of mentioned researches was the Lake's protection from overpumping, e.g. from over declining of the water level that could permanently result in salination of fresh water. On the other hand attention should also be focused on possible contamination of water with pollutants that could enter the Lake through underground. Inside of the Lake's catchment area is 5 to 6 km long part of the magistral road and it presents potential contamination source. Present work analyses mechanisms of the potential contamination of the Lake's system. Interrelation between dynamic of fluctuations of underground and Lake's water level and the regime of functioning of the Lake's karst aquifer were performed. Results show that single pollution incident could permanently devastate lake with the resulting loss of water supply.

Key words: Vrana Lake, island karst aquifer, protection of the lake water, pollution incident

Introduction

In the context of judgment of the risk of ultimate lake's pollution, present paper analyzes hydrology of the specific karst phenomenon – cryptodepression Vrana Lake on the island of Cres (Fig1.). The reason why this lake should be considered as phenomenon is its dimensions compared to the size of the island and the fact that there are no visible inflows and runoffs from the lake.
The island of Cres consists mainly of cretaceous and Eocene carbonate karstified rocks, limestones and dolomites. In lithological sense dolomites are more dominating than limestones and minor occurrences of Paleogene flysch should be mentioned. Quaternary deposits are presented by slope deposits and talus material in lake's aquifer as well as lacustrine silty Pleistocene sediments more than 30 m height, flood deposits and recent lacustrine sediments, on the bottom of the lake (Biondić et al., 1995). The lake's surface area is 5,75 km^2 and the immediate-orographic catchment area of the lake is 33 km^2. The largest depth of the lake is 61.3 m a.s.l. and the average water level in the lake is 13.1 m a.s.l. The

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water in the lake is of extreme quality so it can be used for consumption without any treatment in amounts of about 2 millions m^3 per year. The lake is the only source of water supply for the islands of Cres and closely located Lošinj.

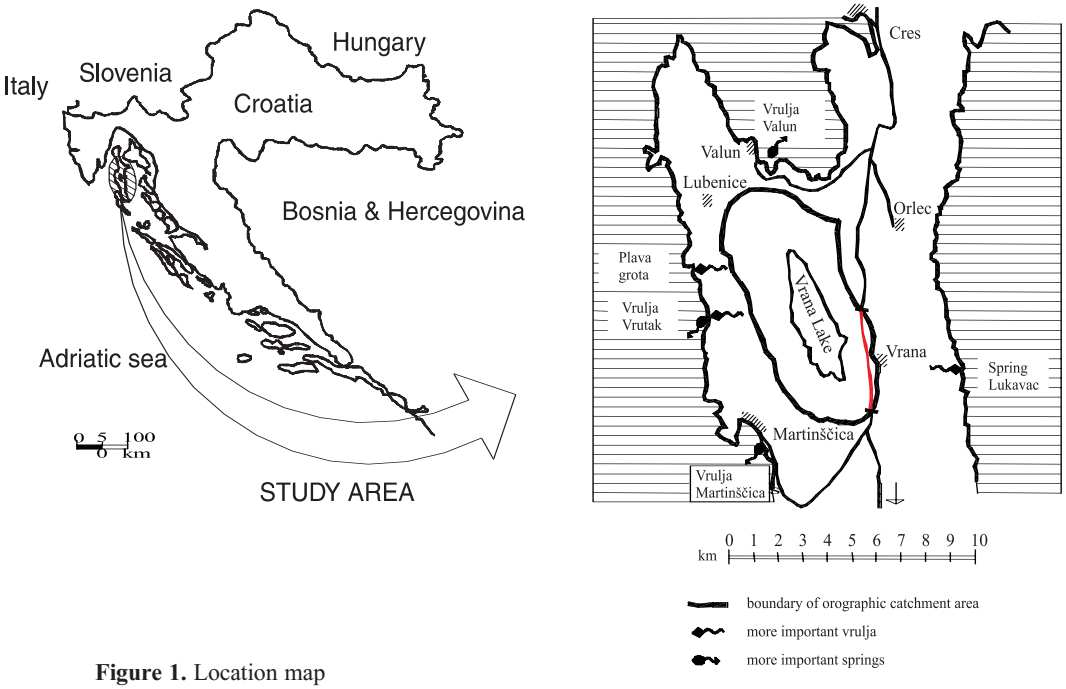

Figure 1. Location map

Extreme trend of water level decrease was recorded during eighties (48 cm per year). That was the reason of great concerning in the context of further existence of dynamic balance of fresh water lens as the protection of seawater penetration into the karst aquifer. These are the causative reasons for the beginning of realization of complex research project with two main objectives of the research: I. protection of the lake from overpumping and seawater penetration into it and II. protection of water from anthropogenic influence in catchment area. The important part of this project was hydrological research that has consisted of analyzes of several basic hydrological parameters with available recorded data. Because of the fact that the lake is karst phenomenon with no visible inflows and runoffs the analysis of dynamics of the lake's system was conducted according to the analysis of the water levels (volumes) in different hydrological conditions and dependent on other measured hydrological parameters.

RESULTS AND DISCUSSION

Basic available hydrological data are as follows: average annual precipitations for Vrana lake catchment is 1068 mm, average annual evaporations from the water surface is 1153 mm and the average annual water level is 13.10 m a.s.l. It was determined that because

of its dimensions lake reactions are relatively inert. The conducted autocorrelation analysis of average monthly water levels showed that there exists a long period of duration of significant interrelations of water levels of the lake – 38 months.

During analyzed 67-years period average annual inflows were between 0.273 m^3s^{-1} (1938) and 1.143 m^3s^{-1} (1960) with the mean value of 0.588 m^3s^{-1}. Because of the large surface of the lake compared with the catchment area, significant part of total inflows into the lake are precipitations directly to the lake's surface (33 %). The remaining part is inflows from the rest of catchment area. According to the results of performed modeling it was determined that the surface of catchment area that optimally satisfied balance conditions of conducted model analyzes is approximately 24 km^2. With such obtained parameters it was determined that the time of total water exchange in the lake is extremely long. According to the analysis (Ozanić, 1996) the retention time required for water exchange in lake is estimated to 31 years.

The results of natural isotopes researches give the retention time for water exchange between 30 and 40 years (Hertelendi et al., 1994). Similar results were obtained by geochemical water analysis where model analysis showed that proportion of underground water of long term in the aquifer is only seven percent. Under these circumstances the largest hazard to the lake comes from the road which in the area of the community Vrana passes for 4,5 km along the edge of the direct catchmant area. The results of measurements of underground water levels suggest the presence of flow gradient from the road toward the lake. The road is of low category, narrow and with a number of horizontal and vertical curves, without any rainwater ditch. The lake is endangered by constant quantities of pollutants from the regular use of the road, as well as by the latent real risk of accidental pollution due to a road accident. The influence zone of the road on the aquifer is probably larger than the area where the road passes through the direct catchment area. The shortest distance from the road to the lake is only 800 m, on altitudes between 200 and 280 m a.s.l. on the area consisting mainly of less permeable dolomite rock. Due to the nearness of the lake, steep slope, and the formed hydrographic network in this part of the catchment area, any accident involving spilling of a larger quantity of liquid fuel or other hazards substances would result in immission of such substances into the lake, and thereby in its pollution.

The Vrana Lake is kryptodepression, and the breathing mechanism of the karst aquifer is very specific. If any of the liquid pollutants, e.g. oil derivatives, comes into the underground, it will, sooner or later, come into contact with ground water of the lake system, and with respect to the geological texture of the terrain, even surface washing into the lake is possible. Once the polluted water comes into contact with the lake system, there is no possibility of its natural outflow from the lake, neither it is possible to achieve by pumping out of the lake. The lake has the volume more than hundred times the annual quantity pumped out, and pumping out of the lake even in such long periods, except lowering its level by several meters, is not possible due to the fact that the lake system "breathes" together with its underground, thus maintaining the balance with the sea. The natural inflows and outflows in the Vrana Lake aquifer do exist, but they are, compared to the aquifer volume, too small to accomplish self-cleaning of the lake once it is polluted. The hazard of pollution caused by, e.g. an accident involving a tank truck loaded with some oil derivative is quite

realistic. The entire road traffic towards the southern part of Cres and the island of Lošinj goes by this road. According to the fuel sales data of the oil company supplying the islands, the transport of oil products by this road in the pre-war years was about 7000 m^3 per annum, or on average more than one tank truck per day.
For the it is necessary to start implementing at least some essential precaution measures - like banning of transport of hazardous substances from the Vrana Lake area, and redirecting of such transport to the sea, or at least, increasing of the traffic safety during transport of such hazardous substances.

CONCLUSIONS

Hydrological and model analyzes conducted have shown that the dynamics of water fluctuation in Vrana lake is directly caused by local – island hydrological conditions. It was determined that besides extreme lake's dimmensions compared to limited island's area the lake can function as a part of island karst aquifer. The results of conducted model calculations and other hydrological analyzes although partly based on different hydrological bases and approaches are analogus. This fact emphasizes the potential hazard and respective necessity of adequate protection of lake's area from the possible ultimate pollution from local island catchment area or in the context of protection from ultimate salination as the consequence of overpumping.
As regards the protection of the water quality, it is necessary to intensify immediately the implementation of necessary safety measures. This refers, in particular, to urgent introduction of measures to prevent accidental pollution from the roads in the direct catchment area of the Vrana Lake. However, it is also necessary to reduce the hazards from possible continuous adverse human influences from the areas close, or slightly remote from the lake.

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