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INVESTIGATION OF GROUNDWATER INFILTRATION TO SEAWATER IN PUNAT BAY, CROATIA, BY MEASUREMENTS OF CONDUCTIVITY AND STABLE ISOTOPES IN WATER

RAZISKAVE ODTEKANJA PODTALNICE V MORJE V PUNATSKEM ZALIVU (HRVAŠKA) S POMOČJO STABILNIH IZOTOPOV IN MERITEV PREVODNOSTI VODE

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N. Horvatinčić & M. Groening & N. Mikulić, J. Obhođaš & V. Valković: Raziskave odtekanja podtalnice v morje v punatskem zalivu (hrvaška) s pomočjo stabilnih izotopov in meritev prevodnosti vode

Mesta odtekanja sladke vode v Punatski zaliv so bila določena na osnovi prostorske porazdelitve prevodnosti in izotopske sestave vodika ($^2H/H$) in kisika ($^{18}O/^{16}O$) v morski vodi. Meritve so opravljali v treh obdobjih - poleti (25 vzorčevalnih mest), jeseni (12) in pozimi (20). Analizirali so tudi vzorce sladke vode iz sedmih izvirov in dveh akumulacij na otoku Krku. Koordinate vzorčevalnih mest so določene z GPS. *In-situ* so določali prevodnost, slanost, temperaturo in pH vzorcev. Povečan dotok sladke vode je bil zaznan poleti in pozimi na severni in vzhodni obali zaliva, jeseni pa le na severni obali. Izotopska sestava izvirov na Krku kaže na hitro kroženje podtalnice, predvsem v deževnem zimskem času.
Ključne besede: onesnaženje morske vode, prevodnost, stabilni izotopi, Hrvatska, Krk, Punatski zaliv.

Abstract UDC: 556.14(497.5)
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N. Horvatinčić & M. Groening & N. Mikulić, J. Obhođaš & V. Valković: Investigation of groundwater infiltration to seawater in Punat Bay, Croatia, by measurements of conductivity and stable isotopes in water

Locations of freshwater infiltration from the coast to the seawater of the Punat Bay were determined based upon the distribution of conductivity and hydrogen ($^2H/^1H$) and oxygen ($^{18}O/^{16}O$) stable isotope signatures of the seawater. Seawater samples in Punat Bay were measured and collected in three seasons: summer (25 sites), autumn (12 sites) and winter (20 sites). Freshwater samples from 7 springs and 2 accumulations on Krk Island were also collected. The position of each sampling site was determined by GPS. Conductivity, salinity, temperature and pH were measured *in situ.* Higher freshwater input was defined on the east and north coast of Punat Bay in the summer and winter seasons, and on the north coast in autumn. Stable isotope composition of freshwater from springs on Krk Island indicated fast circulation of groundwater, particularly in the wet winter season.
Key words: seawater pollution, conductivity, stable isotopes, Croatia, Krk Island, Punat Bay.

INTRODUCTION

The coastal region of Croatia is a highly touristic area. The rocky terrain of the coastal area is mainly characterized by water-permeable karst carbonate. Because of this waste management represents a very complex problem that needs to be properly managed in order to minimize negative effects on the environment.

The potential sources of pollution in Punat Bay, Krk Island, Adriatic Sea, include the marina in Punat, fertilizers and herbicides used for agriculture in the coastal environment, as well as the waste disposal site located uphill of the town (Figs. 1 and 2). The pollution of Punat Bay has been studied by measurements of heavy metals in marine sediment, the water column and benthos. The results of the analysis for lead, zinc and copper pollution were published in Legović et al., 1990b. Estimation of diffuse inputs to the coastal sea using a two-dimensional transport model, and measurements of total concentrations of lead were made by Legović et al., 1990a. The concentrations of more than 20 elements (from K to Pb) in sediments were determined using PIXE and XRF techniques (Valković and Bogdanović, 1996). Limić and Valković (1996) showed that a modelling approach based on the interpretation of pollutant concentrations in sediments can be utilized for determination of the contribution from each individual source of pollution.

Input of freshwater by infiltration of precipitation and groundwater from the coast to Punat Bay can be significant due to the karst terrain on Krk Island. No significant direct runoff from streams into the bay exists. In order to identify locations of freshwater input into the bay we used conductivity and salinity measurements as well as hydrogen ($^{2}H/^{1}H$) and oxygen ($^{18}O/^{16}O$) stable isotope

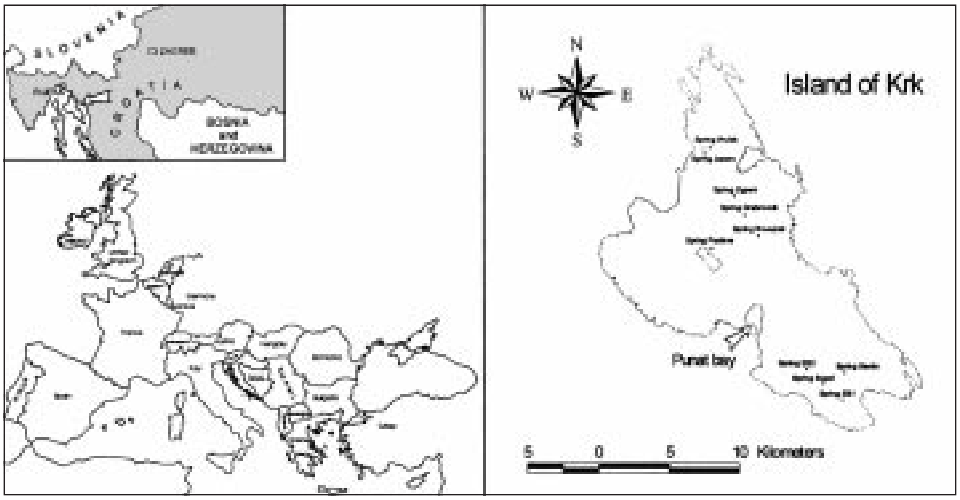

Fig. 1: a) Location of Krk Island in the northern Adriatic Sea, b) Map of Krk Island with springs and accumulations of freshwater, and location of Punat Bay.
Sl. 1: a) Lega otoka Krka v Severnem Jadranu, b) zemljevid Krka z izviri, akumulacijami in Punatskim zalivom.

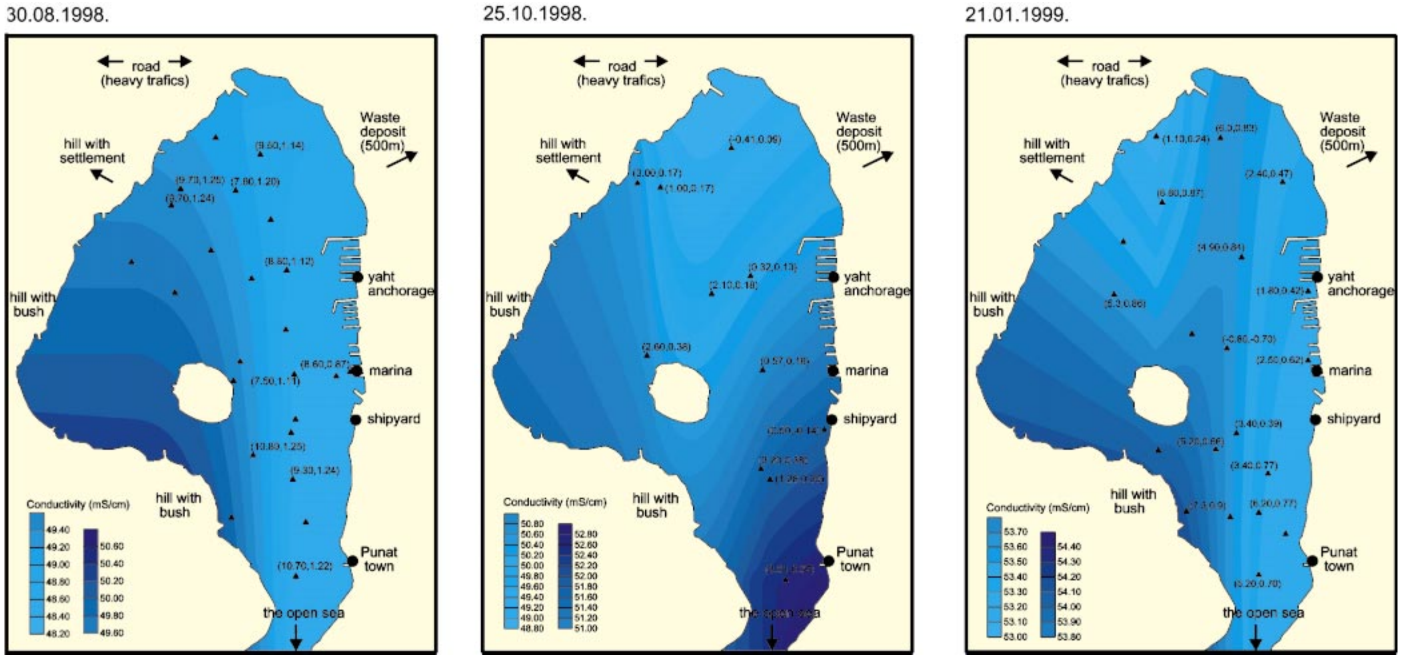

Fig. 2: Distribution of conductivity of seawater in Punat Bay in August and October 1998 and January 1999. The number at the sampling site represents Sample No. from tables 1, 2 and 3 and numbers in parentheses represent δ^2H and $\delta^{18}O$ values.

Sl. 2: Porazdelitev prevodnosti morske vode v Punatskem zalivu avgusta in oktobra 1998 in januarja 1999; v oklepajih so vrednosti δ^2H in $\delta^{18}O$ na posameznih vzorčevalnih mestih.

composition of the seawater. Additionally, temperature and pH values were measured. The same parameters were also measured in the freshwater of springs and accumulations at the Krk Island.

AREA DESCRIPTION

Krk Island is situated in the karst area of the northern Adriatic Sea. The geological structure of Krk Island is composed of carbonate rocks of Cretaceous and Eocene age, breccia of Tertiary age and Quaternary sediment. The hydrogeology of Krk Island is mainly characterized by Quaternary sediments with aquifers of poor transmisivity, and carbonate rocks with aquifers of good and average permeabilty (Hydrology and geology map of Krk Island with protection zones of springs, Faculty of geology, mining and petroleum engineering). Groundwater movements are very complex and depend upon the tectonic structure of rocks of different permeability.

Punat Bay on Krk Island in the northern Adriatic Sea has an area of 2.4 km^2, an average depth of 3.2 m and a volume of 7.7×10^6 m^3 (Figs.1 and 2). The bay is connected to the sea through a narrow mouth, 200 m wide. The Bay is surrounded by hillocks that slope slightly toward the bay. The small town of Punat, a shipyard, and a marina are located on the coast of the bay. A potential source of pollution is also the waste disposal site located uphill of the town.

SAMPLING AND METHODS

Seawater samples from Punat Bay were measured and collected in three seasons: in summer (August 30, 1998) at 25 sites, in autumn (October 25, 1998) at 12 sites and in winter (January 21, 1999) at 20 sites. (Tables 1, 2 and 3). Sampling was performed between 10 and 12 a.m. during high water tide. Tidal range in this region is 20-50 cm depending upon winds. The position of each sampling site was determined by GPS. Conductivity, salinity, temperature and pH were measured *in situ* 2 m below the surface (in August and October) and 0.5 m below the surface (in January). Measurements of seawater conductivity and temperature at the same locations, but at different depths, showed the same values at 2 m, 1 m and 0 m from the surface (Table 1, samples No. 23, 24 and 25). Samples for measurement of stable isotope concentrations ($^2H/^1H$ and $^{18}O/^{16}O$) were collected and stored in plastic bottles and measured by a mass spectrometer at the IAEA Isotope Hydrology Laboratory. Freshwater samples from 7 springs and 2 accumulations at the Krk Island were also collected (Fig. 1b). Samples were collected during July and August 1998 at 8 sites (Table 4) including 1 seawater sample (sample No. 7) close to Vela voda spring, and during January 1999 at 8 sites (Table 5). A sample of water from a small water pond found on the hill, ~ 50 m above sea level, was also analyzed (Table 5, sample No. 7).

RESULTS AND DISCUSSION

The conductivity and salinity of seawater (conductivity: 46.8-55.0 mS/cm; salinity: 29.2-35.3‰) (Tables 1, 2 and 3) was much higher than that in freshwater (conductivity: 0.5-0.9 mS/cm; salinity 0.3-0.5‰) (Tables 4 and 5). The exceptions were Vela voda spring (Table 4, sample No. 6, con-

Table 1: Seawater samples collected in Punat Bay on 30. 08. 1998, between 10 and 12 a.m. (measured at 2 m below the surface). Latitude and longitude are given in degrees, minutes and thousandths. Samples No. 23, 24 and 25 are at the same location but at different depths from the surface, 2 m, 1 m and 0 m.
Tabela 1:Vzorci morske vode pobrani v Punatskem zalivu 30.8.1998 (2 m pod gladino). Vzorci št. 23, 24 in 25 so pobrani na istih mestih v različnih globinah (2m, 1m, 0m).

Sample No	Location		T (°C)	Conductivity (mS/cm)	Salinity (‰)	δ^2H (‰ SMOW)	δ^{18}O (‰ SMOW)
	Latitude (N)	Longitude (E)					
1	45-00-876	14-37-383	18.6	46.8	29.2	10.8	1.25
2	45-00-926	14-37-452	18.5	48.4	30.2		
3	45-01-013	14-37-516	18.5	48.4	30.2	10.7	1.22
4	45-01-131	14-37-546	18.5	48.7	30.4		
5	45-01-224	14-37-505	18.7	48.5	30.3	9.3	1.24
6	45-01-355	14-37-513	19.1	48.5	30.3		
7	45-01-453	14-37-508	19.2	48.5	30.3	7.5	1.11
8	45-01-550	14-37-482	19.3	48.6	30.4		
9	45-01-680	14-37-484	19.4	48.7	30.4	8.8	1.12
10	45-01-790	14-37-434	19.4	48.8	30.5		
11	45-01-932	14-37-401	19.6	48.9	30.6	9.5	1.14
12	45-02-061	14-37-376	19.7	49.0	30.6		
13	45-02-253	14-37-326	19.8	49.1	30.7	7.6	1.20
14	45-02-368	14-37-264	19.5	49.1	30.7		
15	45-02-220	14-37-129	19.8	49.2	30.7	9.7	1.24
16	45-02-030	14-37-141	19.7	49.3	30.8		
17	45-01-856	14-37-157	19.7	49.4	30.9	9.7	1.25
18	45-01-722	14-37-251	19.7	49.5	30.9		
19	45-01-697	14-36-873	19.8	49.5	30.9		
20	45-01-480	14-36-942	19.5	49.5	30.9		
21	45-01-438	14-37-322	19.7	49.6	31.0		
22	45-01-449	14-37-637	19.1	49.8	31.1		
23	45-01-464	14-37-680	19.3	49.8	31.1	8.6	0.87
24	45-01-464	14-37-680	19.3	49.8	31.1		
25	45-01-464	14-37-680	19.3	49.8	31.1		
26	45-00-735	14-37-292	18.8	50.8	31.7		
27	45-00-682	14-37-124	18.8	50.8	31.7		

Table 2: Seawater samples collected in Punat Bay on 25.10.1998, between 10 and 12 a.m.. (measured 2 m below the surface). Latitude and longitude are given in degrees, minutes and thousandths.
Tabela 2: Vzorci morske vode pobrani v Punatskem zalivu 25.10.1998 (2 m pod gladino).

Sample No	Location		Conductivity (mS/cm)	Salinity (‰)	δ^2H (‰ SMOW)	$\delta^{18}O$ (‰ SMOW)
	Latitude (N)	Longitude (E)				
1	45-00-864	14-37-395	51.0	31.4	3.0	0.38
2	45-00-997	14-37-517	50.7	31.9	3.2	0.38
3	45-01-205	14-37-535	52.5	32.5	3.8	0.37
4	45-01-380	14-37-538	53.3	33.0	1.3	0.30
5	45-01-560	14-37-520	51.8	32.1	0.6	0.16
6	45-01-715	14-37-491	50.1	31.0	0.3	0.10
7	45-01-925	14-37-445	49.1	30.4	-0.4	0.09
8	45-02-085	14-37-401	49.1	30.4	2.1	0.18
9	45-02-260	14-37-281	48.0	29.7	1.0	0.17
10	45-01-867	14-37-228	51.2	31.7	3.0	0.17
11	45-01-583	14-36-852	53.0	32.8	2.6	0.38
12	45-01-462	14-37-664	52.5	32.5	0.5	-0.14

ductivity 6.74 mS/cm) and a small water pond (Table 5, sample No. 7, conductivity 1.19 mS/cm). Vela voda spring is very close to the sea shore (~10 m) and the water is partly mixed with seawater. The water pond originated from precipitation that percolated through the soil, and the higher concentration of dissolved salts increased the conductivity of the water. The water pond was found only in the wet winter season. A significant difference in precipitation between the dry summer and wet winter seasons at Krk Island was observed. At the meteorological station Malinska-Krk, ~20 km from Punat Bay, there was 27.7 mm of rain in August 1998, and the five-month average, April-August 1998, was 61.8 mm. In January there was 105.8 mm of rain, and the five-month average, September 1998-January 1999, was 189.9 mm (Meteorological and Hydrological Service, Zagreb). Some discrepancy between conductivity and temperature in different seasons was noticed. For example, during the dry summer (August measurements) with seawater temperatures of 18.5-19.8°C, the conductivity was lower (46.8-50.8 mS/cm) (Table 1) than during the wet winter (January measurements) with seawater temperatures of 5.7-10.4°C and conductivity of 50.5-55.0 mS/cm (Table 3). We expected just the opposite because higher freshwater input during the wet season decreases the conductivity of seawater. The possible explanation for this discrepancy was different conditions of conductivity measurements. For summer and autumn measurements we used a measuring cell with a 50 m long cable and all measurements were done 2 m below the surface, and for winter measurements we used another measuring cell with a 2 m long cable and the measurements were

Table 3: Seawater samples collected in Punat Bay on 21.01.1999, between 10 and 12 a.m.. (measured at 0.5 m below the surface). Latitude and longitude are given in degrees, minutes and thousandths.
Tabela 3:Vzorci morske vode pobrani v Punatskem zalivu 21.01.1999 (0,5 m pod gladino).

Sample	Location		T	pH	Conductivity	Salinity	δ^2H	δ^{18}O
No	Latitude (N)	Longitude (E)	(°C)		(mS/cm)	(‰)	(‰ SMOW)	(‰ SMOW)
1	45-00-745	14-37-310	10.4	7.98	55.0	35.3	7.3	0.90
2	45-00-875	14-37-396	8.3	8.00	53.1	33.9	5.2	0.66
3	45-01-012	14-37-525	8.5	8.16	53.3	34.0	5.2	0.70
4	45-01-143	14-37-534	8.7	8.15	53.4	34.0	6.2	0.77
5	45-01-225	14-37-551	8.0	8.19	53.2	33.9	3.4	0.77
6	45-01-310	14-37-640	9.3	8.16	51.5	32.2	3.4	0.39
7	45-01-458	14-37-676	9.2	8.23	53.5	33.3	2.5	0.62
8	45-01-488	14-37-428	5.7	8.21	50.5	32.7	-0.8	-0.07
9	45-01-631	14-37-663	9.7	8.20	53.2	34.3	1.8	0.42
10	45-01-838	14-37-590	8.4	8.22	53.3	34.2	2.4	0.47
11	45-02-080	14-37-470	8.3	8.26	53.6	34.2	4.9	0.84
12	45-02-330	14-37-406	8.2	8.25	53.7	34.2	6.0	0.83
13	45-02-333	14-37-216	7.2	8.25	53.0	34.0	1.1	0.24
14	45-02-000	14-37-093	8.7	8.26	53.9	34.4	5.3	0.86
15	45-01-794	14-36-834	8.2	8.29	53.6	34.2	6.6	0.87
16	45-01-711	14-36-720	8.1	8.26	53.8	34.2		
17	45-01-518	14-36-924	7.9	8.23	53.0	33.7		
18	45-01-273	14-37-226	7.8	8.27	53.0	34.1		
19	45-01-133	14-37-440	8.2	8.26	53.1	33.8		
20	45-01-098	14-37-604	9.4	8.28	52.9	34.0		

performed at 0.5 m below the surface. Therefore, the absolute values of conductivity (salinity) are not comparable between different seasons.

Distributions of conductivity in Punat Bay in three different seasons are presented in Fig. 2. The number at each sampling site represents the Sample No. from tables 1, 2 and 3, and the numbers in parentheses represent δ^2H and δ^{18}O values. Lower conductivity (light green) indicates possible locations of higher freshwater input from the coast. Some seasonal variations were evident. August and January conductivity distributions showed similar patterns with lower conductivity on the east and north coast of the bay. October measurements showed lower conductivity on the north coast.

Table 4: Freshwater samples from springs and accumulations at Krk Island collected on 16.07.1998. and 30.8.1998. Sample No. 7 is a seawater from the seashore close to the Vela Voda spring.
Tabela 4: Vzorci sladke vode in vode iz akumulacij na Krku zbrani 16.7.1998 in 30.8.1999; vzorec št. 7 predstavlja morska voda z obale blizu izvira Vela voda.

Sample No	Location name	T (°C)	pH	Conductivity (μS/cm)	Salinity (‰)	δ^2H (‰ SMOW)	$\delta^{18}O$ (‰ SMOW)
1	Ponikve accum., Vela Fontana, tap	21.3	6.97	743	0.44	-28.9	-4.21
2	Vela Fontana-closed spring	25.8	7.08	547	0.32	-24.4	-3.39
3	Ponikve accumulation- dam	26.0	7.38	469	0.27	-23.8	-3.29
4	Water station Jezero-Njivice lake	23.6	7.49	596	0.35	-22.6	-3.03
5	Njivice Lake-surface	24.9	7.67	587	0.34		
6	Vela voda- spring (30.8.98.)	14.2	7.78	6.74 (mS/cm)	3.96	-34.3	-5.90
7	Vela voda-gat , sea w. (30.8.98.)	19.6	8.16	54.4 (mS/cm)	32.0	-37.1	-5.89
8	Zanac spring					-42.5	-6.93

Table 5:Freshwater samples from springs and accumulations at Krk Island, collected on 20.-21. 01.1999.
Tabela 5: Vzorci sladke vode iz izvirov in akumulacij na Krku, pobrani 20.-21.01.1999.

Sample No	Location name	T (°C)	pH	Conductivity (μS/cm)	Salinity (‰)	δ^2H (‰ SMOW)	$\delta^{18}O$ (‰ SMOW)
1	EB-2- Baska, spring (tap)	10.3	7.69	760	0.43	-40.4	-6.72
2	Vrbnik-Rogoznik, spring (tap)	9.0	7.32	667	0.38	-35.5	-5.89
3	Dobrinj-Ogreni, spring (tap)	8.5	7.61	702	0.41	-36.0	-6.01
4	Ponikve-Vela fontana, spring (tap)	9.7	7.58	751	0.43	-36.1	-5.80
5	Njivice-Vrutak, spring (tap)	13.4	7.13	896	0.52	-37.3	-6.14
6	Njivice Lake	5.8	7.94	554	0.32	-31.8	-5.09
7	Water pond above Kanajt (on hill)	9.9	7.09	1191	0.69	-30.9	-5.25
8	Ponikve accumulation					-37.0	-5.87

The concentrations of stable isotopes (δ^2H and $\delta^{18}O$ expressed in ‰ according to the SMOW standard) were also much higher in seawater (δ^2H: from -0.8 to 10.8‰; $\delta^{18}O$: from -0.07 to 1.25‰) (Tables 1, 2 and 3) than in freshwater (δ^2H: from -40.4 to -22.6‰; $\delta^{18}O$: from -6.9 to -3.0‰). (Tables 4 and 5). Seasonal variations of δ^2H and $\delta^{18}O$ values were evident for both freshwater and seawater.

δ^2H vs. $\delta^{18}O$ values were correlated with the Global Meteoric Water Line (GMWL: $\delta^2H = 8\ \delta^{18}O + 10$ ‰) (Fig. 3). The stable isotope composition of groundwater was lower in winter (mean values: $\delta^2H = -36.2 \pm 2.5$‰; $\delta^{18}O = -5.94 \pm 0.48$‰) and was very close to the GMWL. This indicated fast infiltration of surface waters caused by strong precipitation in winter. Freshwater samples collected in summer showed generally higher concentrations of ^2H and ^{18}O (mean values: $\delta^2H = -24.9 \pm 2.4$‰; $\delta^{18}O = -3.48 \pm 0.44$‰) and larger deviation from the GMWL that was caused by evaporation due to higher summer temperature. Correlation of δ^2H and $\delta^{18}O$ values of seawater in different seasons is presented in Fig. 4. The lowest concentrations of the heavy isotopes ^2H and ^{18}O in seawater were measured in the samples collected in October 1998 (mean values: $\delta^2H = 1.7 \pm 1.3$‰; $\delta^{18}O = 0.21 \pm 0.15$‰) and the largest fluctuations of δ^2H and $\delta^{18}O$ values were in winter (mean values: $\delta^2H= 4.0 \pm 2.2$‰; $\delta^{18}O = 0.62 \pm 0.27$‰). These effects are the results of the temperature variations and evaporation effect, respectively. Higher freshwater input during the wet season (autumn and winter) also has a similar influence.

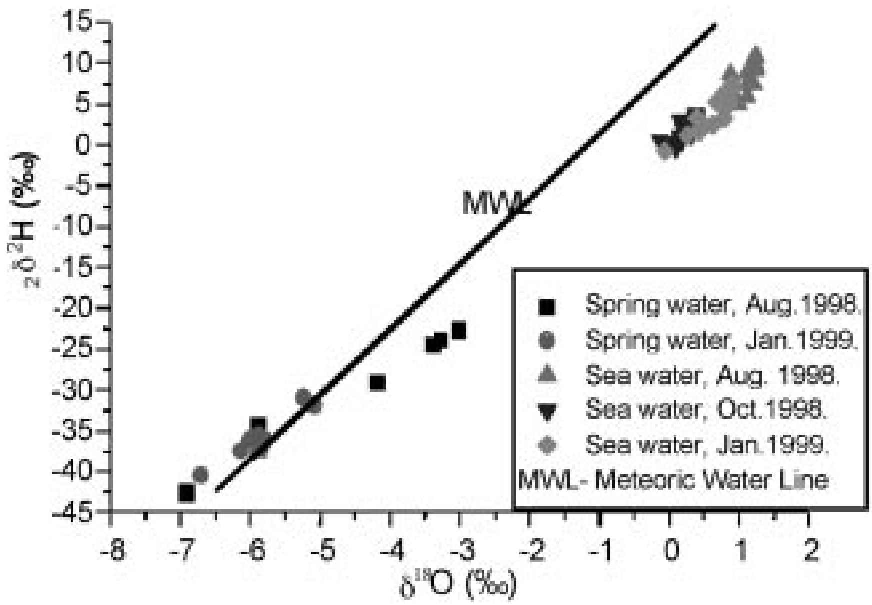

Fig. 3: δ^2H vs. $\delta^{18}O$ values of groundwater samples from springs and accumulations collected at Krk Island and of seawater samples collected in Punat Bay, Krk Island. Samples were collected in different seasons. Stable isotope values were correlated with the Global Meteoric Water Line (MWL).
Sl. 3: Zveza med δ^2H in $\delta^{18}O$ v podtalnici izvirov in akumulacij na otoku Krku ter v morski vodi Punatskega zaliva. Vzorci so bili pobrani v različnih obdobjih. Vrednosti d so korelirane s splošno meteorno premico.

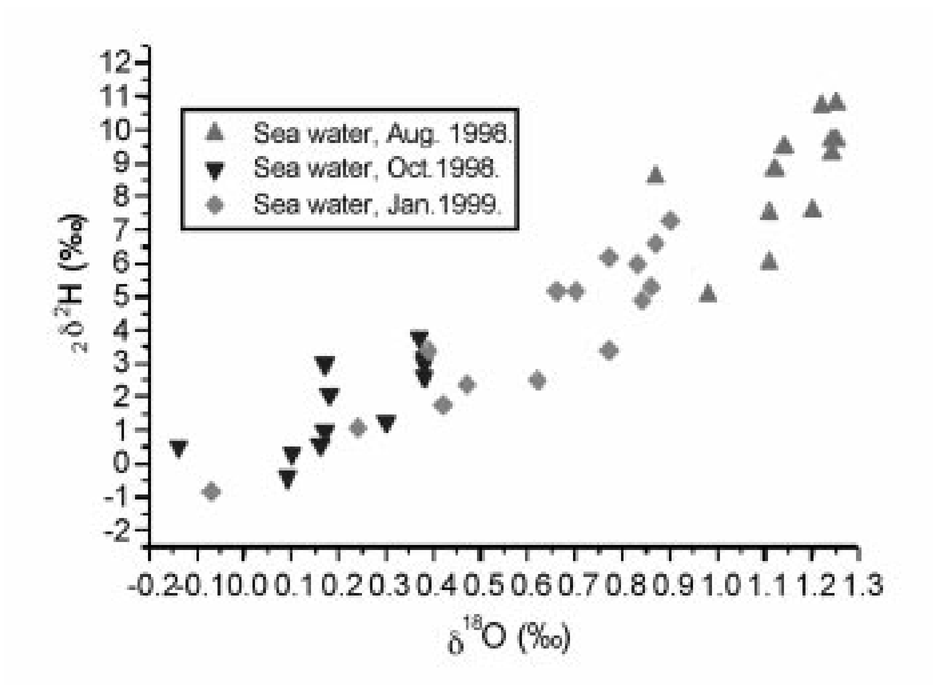

Fig. 4: δ^2H vs. $\delta^{18}O$ values of seawater samples collected in different seasons in Punat Bay, Krk Island.
Sl. 4: Zveza med δ^2H in $\delta^{18}O$ morske vode v Punatskem zalivu, otok Krk, v različnih obdobjih.

The relationship between conductivity and stable isotope signatures of seawater in Punat Bay is presented in Fig. 2. In most cases lower δ^2H and δ^{18}O values belonged to the sites with lower conductivity, particularly in winter, indicating locations with higher infiltration of freshwater. In this study we did not take into consideration the influence of water exchange driven by tides, winds and density differences within the bay that also have an important role in water circulation.

CONCLUSIONS

Locations of freshwater infiltration from the coast to the seawater of Punat Bay were determined based on the distribution of conductivity and hydrogen ($^2H/^1H$) and oxygen ($^{18}O/^{16}O$) stable isotope composition of the seawater. Higher freshwater input was observed on the east and north coast of the bay in the summer and winter seasons, and on the north coast in autumn. Additional measurements in different seasons, particularly after heavy rains, will help for more precise determination of freshwater infiltration to the seawater.

The stable isotope composition of freshwater from the springs at the Krk Island indicated fast circulation of groundwater, particularly in the wet winter season.

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RAZISKAVE ODTEKANJA PODTALNICE V MORJE V PUNATSKEM ZALIVU (HRVAŠKA) S POMOČJO STABILNIH IZOTOPOV IN MERITEV PREVODNOSTI VODE

Povzetek

Potencialni izvori onesnaženja v Punatskem zalivu (otok Krk, Hrvaška) so marina v Punatu, uporaba gnojil in herbicidov na kmetijskem obalnem področju in lokalno odlagališče odpadkov nad mestom (slike 1 in 2). Zaradi zakraselosti terena je dotok sladke vode v zaliv pomemben, tako s prenikanjem padavin kot tudi s podzemnimi izviri. Primes sladke vode pomembno vpliva na električno prevodnost in slanost morske vode, kakor tudi na njeno izotopsko sestavo.

Lokacije možnih dotokov sladke vode v Punatski zaliv smo določili z meritvami električne prevodnosti in/ali slanosti ter izotopske sestave vodika ($^{2}H/H$) in kisika ($^{18}O/^{16}O$) morske vode. Merili smo tudi temeraturo in pH. Prevodnost, tempeaturo in pH smo določili *in-situ*, medtem ko smo izotopske meritve opravili z masno spektrometrijo na IAEA v laboratoriju za izotopsko hidrologijo.

Vzorce morske vode smo zbirali v treh obdobjih: poleti (avgusta 1998) na 25 mestih (tabela 1), jeseni (oktobra 1998) na 12 mestih (tabela 2) in pozimi (januarja 1999) na 20 mestih (tabela 3). Koordinate vzorčevalnih mest smo določili z GPS. Vzorce sladke vode iz zbirnega področja Punatskega zaliva smo vzeli na 7 izvirih in 2 akumulacijah na otoku Krku. Analizirali smo 8 vzorčevalnih mest julija 1998 (tabela 4) in januarja 1999 (tabela 5). Prav tako smo analizirali tudi

vzorec vode, za katero menimo, da pronica skozi tla in morda tudi skozi deponijo (tabela 5, vzorec št. 7).

Prevodnost in ustrezna slanost morske vode (prevodnost 46,8 - 55,0 mS/cm; slanost 39,2 - 35,3‰) sta bili mnogo večji v morski vodi kot v sladki (prevodnost 0,5 - 0,9 mS/cm, slanost 0,3 - 0,5‰). Porazdelitev prevodnosti vode v Punatskem zalivu v treh obdobjih je prikazana na sliki 2. Opazili smo nekatera neskladja med prevodnostjo in temperaturo; verjetno so vzrok različni pogoji ob opravljanju meritev prevodnosti.

Koncentracija težkih izotopov vodika in kisika (δ^2H in $\delta^{18}O$, izražena v ‰ glede na SMOW standard) je tudi mnogo višja v morski vodi (δ^2H od -0,8 do +10,8‰, $\delta^{18}O$ od -0,07 do +1,25‰) kot v sladki (δ^2H od -40,4 do -22,6‰, $\delta^{18}O$ od -6,7 do -3,0‰). Sezonska nihanja vrednosti δ^2H in $\delta^{18}O$ so značilna tako za sladko kot morsko vodo. Zvezo med δ^2H in $\delta^{18}O$ smo primerjali s splošno meteorsko premico (GWML, $\delta^2H = 8 \times \delta^{18}O + 10$‰, slika 3). Podtalnica je bila izotopsko lažja pozimi (srednja vrednost δ^2H -36,2 ± 2,5‰ in $\delta^{18}O$ -5,94 ± 0,48‰) in zelo blizu splošni meteorski premici, kar kaže na hitro infiltracijo površinske vode ob izdatnejših zimskih padavinah. Vzorci sladke vode, zbrani poleti, so izotopsko težji (srednje vrednosti δ^2H -24,9 ± 2,4‰ in $\delta^{18}O$ -3,48 ± 0,44‰) in tudi bolj odstopajo od splošne meteorske premice zaradi izhlapevanja ob višjih poletnih temperaturah. Najvišje d vrednosti so bile izmejene oktobra 1998 (srednje vrednosti δ^2H 1,7 ± 1,3‰ in $\delta^{18}O$ 0,21 ± 0,15‰), največja nihanja pa pozimi (srednje vrednosti δ^2H 4,0 ± 2,2‰ in $\delta^{18}O$ 0,62 ± 0,27‰), kar je posledica temperaturnih nihanj in izhlapevanja, prav tako pa tudi večjega dotoka sladke vode v bolj vlažnem obdobju (jeseni in pozimi).

Skladno s porazdelitvijo prevodnosti in izotopske sestave vodika in kisika v morju v Punatskem zalivu smo določili večji vnos sladke vode ob vzhodni in severni obali zaliva poleti in pozimi ter ob severni obali jeseni.