Problems of Water-Supply in the Coast-Insular Area of the Zadar Region

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Abstract

The situation in economic development, especially in tourism and agriculture, as well as demographic changes in the Zadar region are closely connected to infrastructure development, particularly with water-supply.

The intention of this article is to warn about the unsustainable condition in water supply of the insular area.

Applying the statistical data, analyzing the existing condition and using the method of comparison, very contradictory condition in economizing the drinking water in coastal and insular part of the region has been established.

The coastal part has been connected to the water-supply system of the Zrmanja drainage basin i.e. to the regional water-supply system of the Northern Dalmatia, and uses local springs, which enables economic and demographic development of the coastal settlements. On the other hand, the islands of the Zadar archipelago belong to the group of the least developed and socially most neglected parts of the country.

The quality water supply is a very important precondition for the revival of the insular area.

Because of this reasons, the authors think that the quality and constant supply of the islands is the basis for the development of tourism and other economic activities, particularly agriculture.

Introduction

Quality and constant water supply of a certain area is a precondition for demographic and economic development.

Present condition of the Zadar region is marked with discordance between coastal and insular area.

While the regional water-supply system enables constant and quality supply as well as the revival of the economic activities, the insular area still stagnates in its development.

The lack of regular water supply is a crucial problem that provoked depopulation and stopped the development of the economy.

There are no surface flows in the insular area, and brackish water springs are very rare. The present way of water supplying by cisterns, rainwater and water carriers does not meet the local people's needs, let alone the needs of the tourists in the summer.

Researches and Results

Insular Part of the Region

The area of the Zadar archipelago belongs to Csa type of climate with precipitations ranging from 800 to 1000 mm. The main raining period is in the colder part of the year, from September to December. According to the accessible data (Table 1), observing monthly and annual values within the observed area, there are significant differences in disposition and quantity of the precipitations. The average annual values rise from outer, open-sea part of the region towards the coastal sequence of islands.

At the meteorological station in Sali (Dugi otok) the annual quantity of precipitation in the period between 1961 and 1990 was 824 mm, while on the island of Vir, which is a coastal island, the quantity of precipitation in the same period reached the value of 985 mm. The quantity of precipitations decreases from the islands in the northern part of the archipelago (the island

Table 1 – Average month and annual quantities of precipitations in the insular part of the Zadar region in the period 1961-1990

Station	MONTHS													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total annual	% IX-XII month
SILBA	93	75	70	67	64	57	39	69	94	86	133	92	938	58
OLIB	87	82	71	65	60	56	36	67	97	86	132	96	934	59
IST	86	77	70	66	56	49	37	66	95	77	118	93	889	59
MOLAT	79	71	68	61	47	53	30	66	93	70	119	91	848	59
VIR	92	83	80	71	64	51	38	67	98	110	133	97	985	60
ZADAR	77	72	74	60	61	52	35	63	98	112	118	94	915	60
UGLJAN	84	76	75	66	58	56	42	59	97	110	120	94	938	60
BRBINJ	86	74	72	65	55	51	39	53	92	106	120	93	906	61
VELI IŽ	75	66	67	58	50	42	35	58	86	98	114	88	837	61
SALI	83	68	69	55	48	49	30	57	77	90	108	90	824	62

Table 2 – The condition of water supply on Zadar islands

ISLAND	WATER SUPPLY SYSTEM	CISTERNS	WATER CARRIER	UNDERGROUND WATERS	ADDITIONS
SILBA	LOCAL	YES	YES	4 WELLS	Water supply network local cisterns
OLIB		YES	YES	4 WELLS	Spring of brackish water
PREMUDA	LOCAL	YES	YES	3 WELLS	Construction of supply system
ŠKARDA				3 WELLS	
IST	LOCAL	YES	YES	3 WELLS	Construction of supply network
MOLAT	LOCAL	YES	YES	12 WELLS	Construction of new water reservoir
ZVERINAC		YES	YES	2 WELLS	
IŽ		YES	YES	11 WELLS	1 SPRING
RAVA		YES	YES	2 WELLS	
SESTRUNJ		YES		1 WELL	
RIVANJ					
SESTRICA V.		YES			
OŠLJAK		YES	YES		
BABAC				1 WELL	
VRGADA		YES	YES	4 WELLS	

of Silba – 938 mm) towards the southern insular series (Sali – 824 mm).

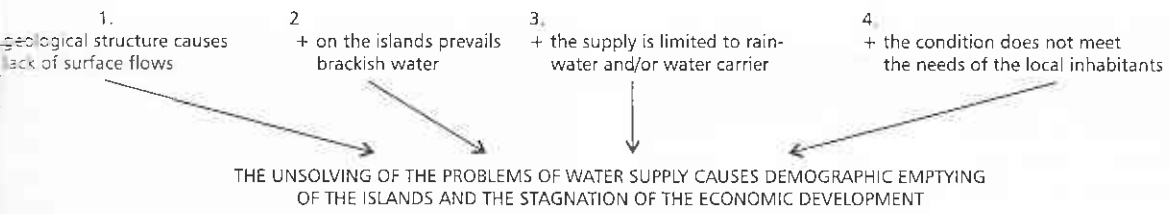
The islands in whose geological structure prevail Cretaceous limestone and dolomites (Olib, Silba, Premuda, Zverinac, Sestrunj, Rivanj, Škrada, Molat) together with local appearances of Eolic limestone (the island of Olib) and Eolic marl (Silba), don't have surface flows. The porous surface enables a direct draining off of water into the underground. The consequence of this situation is the absence of the springs with drinking water, and the appearances of the brackish water are very rare. Such salty water has been spotted on the islands: Silba, Olib, Molat, Iž, Premuda, Škarda, Ist, Rava, Sestrunj, Zverinac, Vrgada and Babac (Table 2).

Although a certain quantity of these waters could be used as technological water or in the households, the main problem is that there are no machines for purifying or for desalinization of these waters.

A detailed analysis of the condition of the smaller islands of the Zadar archipelago indicates very neglected condition of the water supply and the local inhabitants are left to self managing. This analysis includes the northern islands (Silba, Olib, Premuda, Molat), the area of the outer series of islands (Dugi otok) and the coastal series of islands (Ugljan, Vir).

The island of Olib is made of Cretaceous limestone and dolomites with smaller zones of Eocene limestone in the northeast, while the narrow dolomite zone stretches from northwest to southeast. Such structure of the ground causes the absence of surface flows and enables the appearance of smaller puddles in the dolomite zone. There are a few springs of brackish water on the island among which the one found in the Šibenska Bay is the largest. As a result of this situation the supply exclusively depends on the transport of water by a water carrier and individual cisterns.

The major part of Silba is made of Cretaceous limestone, except in the southern part where there are Eocene marls. In wintertime, when the quantity of precipitations is 58% of the total annual quantity, the inhabitants supply themselves mainly by rainwater. On the other hand, in the summer time the water carrier



Graph 1 – Based on the already established, it is possible to differentiate several crucial characteristics of the coastal part of the region:

supports the supply. The island has a water supply network that is connected to the local cisterns.

The island of Premuda has a similar structure; namely, it is made of Cretaceous limestone, and on the northeastern and southwestern side of the island the dry coves end with small overflowed bays. In the bay of Lazi there are springs of brackish water. Premuda has a local water supply system that includes two local and several private cisterns. The supply in the summer is linked to the regular arrival of water carrier.

The island of Molat is made of Lower-Cretaceous and Eocene limestone, which indicates the lack of surface flows and the springs of drinking water. The three dug wells have a capacity that is insufficient for a safer self-supply (less than 0,1 l/sec). Local cisterns (2 × 400 m^3) and several individual ones (114 × 20–30 cm^3) are filled with rainwater and transported water. The water supply system on the island is exclusively of a local character.

The island of Dugi otok in its southeastern part has its own water springs with a capacity of 5 l/sec, but the quality does not meet the standards for drinking water. The water from the well in the Žman field is brought by water conduit to the artificial accumulation Velika Dumbovica near Zaglav including settlements of Luka and Sali. The northwestern part of the island is out of this water supply system.

The island of Ugljan also does not have natural conditions for accumulating larger quantities of drinking water. The hospital on the island uses the water from the well Duboko, but its water often gets salted, which makes this water unsuitable for drinking. The smaller wells are located in the Kukljica area and in the Sutomišcica Bay, but they are also insufficient for satisfying needs during the summertime. The island of Ugljan represents the first step in connecting the coastal area of the region with the islands by a water supply network. A submarine water conduit transports water from the land to Lukoran.

In impermeable flish layer on the island of Vir there are a few wells of brackish water for local needs and numerous individual wells by the weekend cottages.

On the rest of the islands of the Zadar archipelago – Ist, Iž, Rivanj, Sestrunj, Škarda, Tun and Zverinac – the only mean of water supply is also the water stored in the cisterns either as the rainwater or water transported by ships. (Graph 1)

As it has been stated earlier, depopulation of the islands additionally contributes to the problem of water supply, especially on those, traffic isolated islands with almost none or very weak economic activities. Therefore, it is no surprise that the most neglected islands are both those affected by depopulation and those with a negative population growth, with a domination of the old people and/or singles (Table 3). Only Ugljan and Dugi otok can be treated as potential development areas - the island of Ugljan because of its nearness to the regional center (i.e. Zadar) and because of the potential industrialization (ship repairing yard Lamjana) and mariculture (tuna fishery) and Dugi otok because of its fish marinating factory and tourism, particularly nautical tourism in the Telašćica Bay.

However, even the most distant islands have a real chance of becoming innovative focuses based on several basic assumptions:

- the introduction of the ecological agriculture and the production of healthy food on family farms based on the olive cultivation, vineyards, breeding of goats/sheep, the production of healing and aromatic herbs and esstential oils, breeding of bees
- remaking in the small production plants on the level of the village-local community or on the family level
- concentrating tourist activity on the specific qualities of the local rural environment

In order to revitalize the life on the islands it is necessary to fulfill several preconditions:

- to strengthen the traffic lines with the towns on the coast
- to build of the local insular road infrastructure
- to link all inhabited islands to the regional water supply system of the Northern Dalmatia

Coastal Part of the Region

The analysis of the condition of the water supply in the coastal part of the region shows a completely different situation, although up to the 1980s the Zadar re-

Table 3 – The population of the Zadar islands 1981-1991

Island and settlement	NUMBER OF INHABITANTS		INDEX
	1981	1991	1981/91
DUGI OTOK	2099	2873	136,87
BOŽAVA	139	166	119,42
BRBINJ	104	168	161,54
DRAGOVE	78	139	178,20
LUKE	135	164	121,48
SALI	877	1190	135,69
SAVAR	93	85	91,40
SOLINE	145	124	85,52
VELI RAT	167	140	83,83
ZAGLAV	237	369	155,70
ŽMAN	275	328	119,27
IST	299	237	79,26
IŽ	768	567	73,83
MALI IŽ	212	189	89,15
VELI IŽ	556	468	84,17
MOLAT	301	222	73,75
BRGULJE	76	56	85,53
MOLAT	135	114	84,84
ZAPUNTEL	90	52	57,78
OLIB	226	168	74,37
PREMUDA	98	73	74,49
RAVA	147	120	81,63
RIVANJ	30	20	66,67
SESTRUNJ	96	123	128,12
SILBA	198	221	116,62
UGLJAN	6801	7583	111,50
KALI	1829	2245	122,74
KUKLJICA	716	868	121,23
LUKORAN	675	687	101,78
OŠLJAK		65	
POLJANA	448	448	100,00
PREKO	1559	1759	112,83
SUTOMIŠČICA	438	441	100,68
UGLJAN	1136	1070	94,19
VELE SRAKANE	16	9	56,25
VIR	866	860	99,31
VRGADA	311	236	75,88
ZVERINAC	96	59	61,46

gion belonged to those parts of Croatia with significant lack of water.

Water supply of the coastal part is based on the Zrmanja River, whose waters are used by the inhabitants, than it is used for hydro energy and in agriculture. Although the Zrmanja River is the basis for the water supply, along the coastline there are several larger and smaller interventions whose capacities are not sufficient for the existing, let alone for future development activities. Anyhow, they had a very important role during the war when the interventions on the Zrmanja River were disabled. Out of local springs the most important is pumping site Bokanjac Mud, functioning since 1901, which has been simultaneously expanding with the urban development of the city of Zadar by means of opening new wells. Today, only two out of five existing wells are functioning, because during the summer the influx of water is very weak, so that the three other wells dry out. The local settlements, Kožinos, Petrčane, Bibinje and Sukošan supply themselves with water from Bokanjac. The Jezerce well has been used for the needs of the Nin area and adjacent settlements (Ninski Stanovi, Žerava, Poljica, Zaton and Privlaka) since 1966. Additional water supply has been intensified by the wells Boljkovac near the village of Grbe (since 1972) and Golubinka, coastal spring near the village of Vrsi (since 1992). However, the problem of water supply is additionally complicated by the saltiness of the water in Boljkovac well, although it is 2,5 km away from the sea. This is caused by the activation of siphon flows at greater depths while the water flow is stronger.

In the northern coastal part, by the Velebit canal and Novigrad Sea, the water supply partially depends on smaller local springs, which unfortunately are not enough for quality supply during the summertime. The problem is particularly observable in villages Ražanac and Rtina whose wells Ražanac, Mramor and Gradina are not linked to the regional water supply system. On the other hand, the springs Vratrovac, Kneževića vrelo, Jukić I and II, used for supplying the villages Seline and Starigrad, work as a part of the water supply system of the Zrmanja River that also includes the village Posedarje. With this system these villages have solved their long-termed problems that they had been facing during the tourist season and which had been stopping their economic development.

The most important role for the drinking water supply of the whole Zadar area has an intervention on the Zrmanja River. Considering the power of the spring and the capacity, the Zrmanja drainage basin can be divided into constituents:

- the first drainage comprises the springs on the right bank of the Zrmanja River in the area of Lika, northwest of Gračac and the slopes of Velebit mountain up to Muškovci
- the second drainage is the area of the spring of the middle river flow from which the Zrmanja River accepts surface flows
- the upper flow of the Zrmanja River has the least important role for the water supply, as it dries out in summertime

The regional water supply system supplies the Zadar area by a water conduit going from Obrovac to Maslenica, where it branches into three directions:

- Maslenice – Starigrad – Seline
- Maslenica – Karin – Novigrad
- Maslenica – Posedarje – Zadar

Discussion

The complete solution of the water supply problem lies in linking the insular area to the regional network of the Zrmanja River. The third direction of the water conduit coming from Obrovac – Maslenica to Zadar should be expanded to the insular series. The first destination in that network is the Island of Ugljan, i.e. the settlement of Lukoran, and from where all other settlements on the islands of Ugljan and Pašman can be connected to the network. The settlement of Preko can be treated as the node for linking all other islands of the archipelago.

The first direction connects the islands of the northern part: Rivanj-Sestrunj-Tun-Ist-Olib-Silba-Božava. The second direction from Sestrunj leads to Zverinac and northwestern part of Dugi otok (Soline-Božava). The third direction connects Iž-Rava and middle and eastern part of Dugi otok. The coastal islands, Vir and Pag, link themselves through the settlement of Nin.

However, water supply of the whole area is faced with possible pollutions, not only of the local wells but also of the whole Zrmanja drainage basin. The greatest potential danger is linked to the Bokanjac Mud and the flow of the Zrmanja River. In the area of Bokanjac and the nearby military base the issue of sewage system is still not solved. The waste fecal waters penetrate directly into the Karst underground and thus become latent danger for underground waters that flow into the wells. The wastewaters from the settlements contain nitrogenous compounds (ammonia, nitrates, nitrites), chloride, sulphates and phosphates as well as pathogenic microorganisms (agents of typhus, cholera, dysentery), and viruses which cause intestinal and stomach diseases, paralysis, jaundice. The intensive housing construction in the area of Bokanjac additionally burdens the situation. The main pollution can be expected from the main city dump, where industrial and hospital waste is disposed. For the purpose of determining the present situation and the effects of the city dump and fecal waters on the surrounding area, it is necessary to analyze the medical condition of the inhabitants of Bokanjac and surrounding settlements and compare it with the medical condition of the inhabitants from other areas that are not affected by the pollution.

The waters of the Zrmanja drainage basin are not threatened by the industrial or urban pollution since the whole area is not very populated and poorly industrialized. However, very intensive road traffic on the main traffic direction Zagreb-Split on the route Bruvno-Gračac represents the greatest danger, especially because of the sedimentation of heavy metals such as lead, cadmium, and particles of soot. During the wintertime the roads are intensively being covered with salt. With the thawing of the salt, the liquid from the roads pours toward the edges of the pavement and penetrates into the underground and underground waters. Thus, it is necessary to ensure several important preconditions for quality water supply so that the pollution of the underground waters and pump sites springs could be reduced to a minimum:

A. Bokanjac

- to build a sewage system and to recover the septic tanks of the whole area
- to recover the city dump by installing clay or PVC pad, introduce the drainage system, compress the waste and to relocate the dump
- to remove and recover the wild dumps

B. Zrmanja

- to build the drainage system on the roads simultaneously with building of the speedway, i.e. highway, on VPC area

Conclusion

The water supply in Zadar region reveals two completely opposite situations: the coastal part is connected to the regional water supply system of Northern Dalmatia, with main springs on the Zrmanja River, smaller interventions at Bokanjac and local springs in the coastal area; on the other hand, the insular area is still one of the least developed and the most neglected parts of Dalmatia. Water, as the basis for life, is the main factor for the development of every area. Urban development, industry, agriculture and tourism can only be developed if there are enough quantities of water to satisfy the basic needs of each activity. The city as a concentration center does not only require enough water for the needs of the households and economy, but also quality urban development, which supposes significant quantities of water for municipal activities (fountains, parks, horticulture) i.e. for ennobling the surrounding which is specially important in tourist towns like Zadar, Posedarje, Novigrad and Nin.

Studying the islands it is possible to point out several important characteristics:

- water self-supply cannot solve the problem of the economic development
- the lack of economic initiative, which is partially caused by the lack of water, is a reason for depopulation and emptying of the insular area
- the islands are the area of »ECOLOGICAL EMIGRATION« caused by inactivity of the community and the society in general

– WATER is the critical factor on which two possible ways of future heading of the islands depend:
  – connection of the islands to the regional network – and the beginning of the renewal of life on the islands
  – the islands are not important economic zones that should be developed and they should be let to self-survival

Which road to take and which solution to choose primarily depends on the interest of the local and regional community, and than on the state in general.

However, it should also be emphasized that the islands are very important and very quality economic potential in both tourist and agricultural way.

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