ANALYSIS OF WATER USE IN CROATIA ON PRINCIPLES OF SUSTAINABLE DEVELOPMENT

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Abstract: The paper highlights the status of the water use in Croatia. The major findings indicate that water is key to development in Croatia. The goal of paper is to supplement the data for future research in relation to sustainable water use. The problem analysis of water use is based on the application of the European Environment Agency framework for environment assessment: driving forces, pressures, states, impact and responses. The basic source for water use in Croatia is surface water, followed by groundwater and marginal quantities of desalinized water.In Croatia, 38 per cent of water is used for urban purposes, 60 per cent in industry and energetic and 2 per cent in agriculture. The quantity of water used for power production is not included in these indicators, for which purpose Croatia uses 33.5 × 10^6 cum of water per year. Water uses in Croatia varies greatly, depending on natural conditions, culture, and economic conditions. Water resources can meet the water requirement of household, industry, agriculture, power production as well as those needed to resolve problems of the environment and ecosystems.
Key words: water resources, pressures, status, water management, sustainable water use, Croatia

ANALYSE EINER NACHHALTENDEN WASSERNUTZUNG IN KROATIEN

***Zusammenfassung*:** Im Artikel wird die Wassernutzung in Kroatien analysiert. Der Analyse der Wassernutzung liegt ein interdisziplinaeres Identifikationsverfahren, Analyse und Beurteilung der natuerlichen und menschlichen Ablaeufe und deren Interaktionen zugrunde, die den Bestand der Wasserressourcen bestimmen. Die grundquelle zur Wasserschoepfung sind die Obenflaechenwasser, es folgt das Grundwasser und geringe Mengen an entsalztem Wasser. In Kroatien wird 38 Prozent des geschoepften Wassers fuer den urbanen Bedarf, 60 Prozent in der Industrie und Energetik und 2 Prozent in der Landwirtschaft benutzt. Die Wassermenge zur Stromerzeugung ist in den Parametern nicht inbegriffen, und fuer diese Zwecke werden 33,5 x 10^6 m^3 Wasser jaerlich gebraucht. Die Wassernutzung verliert in Kroatien stark, in Abhaengingkeit von den natuerlichen Verhaeltnissen, Kultur und wirtschaftlicher Entwicklung. Die Wasserressourcen Kroatiens genuegen zur Deckung des Bedarfs am Wasser in Haushaeltern, Industrie, Landwirtschaft sowie fuer den Bedarf der Umwelt und oekosystems. Wasser ist der Schluessel der Entwicklung Kroatiens.
Schluesselworte: Wasserressourcen, Belastung, Bestaende, Bewirtschaftung, nachhaltende Wassernutzung, Kroatien

1. Introduction

The paper analyses the use of water in Croatia. Water resources are affected by numerous factors, resulting from agriculture and industry, urban areas, households, and tourism. Other driving forces which influence the water resources are related to natural variability of rainfall and climate changes. Extreme hydrological events, such as floods and droughts create additional stress in the water supply sector, which are important from the health point of view, and to the issues of the ecosystem status. The problem of excessive use of water resources is extremely complex, not from only the hydrological standpoint, but also regarding the socio-economic and political conditions. The solutions must meet the

environmental requirements and be socially and politically feasible. The objective of the paper is to analyse the conditions for improvement of water use, support to sustainable water use and protection of resources. Therefore, it is suggested that the research and collection of data concentrate on improving the present status of information.

2. Elements of environmental assessment and definitions

The study is based on the interdisciplinary process of identification, analysis, and assessment of relevant natural and human processes and their interaction which determines the present and future status and quality of the environment and resources in the corresponding spatial and temporal scale (EEA, 1995). Agriculture, population and its growth, urbanization and industry are the fundamental *driving forces* affecting the hydrological cycle. They result in *pressures* on water resources, such as those related to water abstraction or different uses: municipal use, industry, agriculture, etc. Climate changes are also considered. The *status* of water resources is assessed by their quantity and quality. The *influences* are described through general information and regional examples. The estimate of these influences provides information for setting of goals for future research and policies. Potential social *responses* are described by regulatory instruments, control of water supply and water requirements, financial instruments, and infrastructure. These principles are shown in Table 1.

Table 1. Elements of environmental assessment

Driving forces →	*Pressures* →	*Status* →	*Influences* →
Agriculture	Water abstraction	Runoff	Water stress
Population	Surface water	Renewable	Drought
Industry	Ground water	Resources	Degradation
Climate	Climate changes	Quality	• Quantity
Rainfall			• Quality
Temperature			Ecological status
↑	↑		↓
Policy	*Responses* ←		*Goal Setting*
Laws	Infrastructure		1.
Directives	Supply and		2.
Etc.	demand		.
	Control		.
	Costs		n.

3. Factors affecting the water resources

3.1. *Population and urbanization*

The changes of population number, distribution, and density, are the key factors influencing the assessment of water demand. The number of population in Croatia is given according to census, as follows (SLJH - 2000):

1.	1951	3,876,300	4.	1981	4,601,459
2.	1961	4,159,800	5.	1991	4,784,267
3.	1971	4,426,200	6.	2001	4,381,352

In the Republic of Croatia, 54 percent of the population live in urban centres. Out of this, 16 percent live in towns with the population over 500 thousand, 12 percent in towns with the population of 100-500 thousand, 13 percent in regional centres with the population of 30-100 thousand, 13 percent in minor towns with the population of 7-30 thousand, 27 percent in local

centres with the population of 2-7 thousand, and 19 percent in communities with the population under 2,000 (census 1991). Table 2 gives the data on Croatia, EU member countries, and Europe as a continent (Eurostat, 1997).

Table 2. Data on Croatia, EU member countries and Europe

Country	*Area (000 sq.km)*	*Population, 1996 (000 inhabitants)*	*Population density (per sq.km)*
1. Croatia (1991)	56.5	4,784	84.6
2. EU member countries (15)	3,240.3	372,343	average 115
3. Europe, continent	10,200	680,000	67

Water use in households and small-scale industry shows large variation from country to country. Consumption measured as the quantity and percentage of overall water use is also growing in the majority of countries in the period from 1980 to 1995. It is assumed that the population will grow, with changes in the lifestyle, that the water tariffs will increase, and that the society will show more concern for water. This should result in more economical water use.

3.2. *Industry*

Industrial activities result in pressures on the environment. These may be direct pressures, such as emission of pollutants, production of hazardous waste, and consumption of natural resources. Indirect pressures result from consumption and use of industrial products. In Croatia, the added value of industry in gross domestic product – GDP is around 20 percent. In EU member countries, it is about 30 percent, and in Europe 29 percent. Comparing of data on water use in industry is very difficult, due to inconsistency of data. Water use in industry, excluding cooling water, is about 10 percent, and water used for cooling and power production is 32 percent of all abstracted water. In many European countries water requirements in industry are decreasing. This is, first of all, the effect of economic recession, but also of technological improvements (EC, 1992). The growth of industrial production stagnates and decreases in relations to other sectors of economy.

3.3. *Agriculture*

The agricultural sector creates pressures on water resources by water abstraction and by potential pollution of the resources by fertilizers and pesticides. Agriculture is therefore an important driving force in sustainable water management. In Croatia, agriculture contributes 7 percent to GDP (1998 data). In EU member countries, the contribution of agriculture is 2.3 percent on average, and in Europe 6 percent (FAO, 1996). The total agricultural population in Croatia has been decreasing at the rate of 4.9 percent since 1961. The data on irrigated areas are given in Table 3. A variable role of irrigation in European agriculture is noticed depending, first of all, on climatic conditions.

Table 3. Agricultural and irrigated areas

Country	*Total area (000 sq.km)*	*Total agr. area (000 ha)*	*Percentage of agr. area (%)*	*Irrigated area (000 ha)*	*Percentage of irr. area (%)*
1. Croatia	56.54	3,208	56.7	3.1	0.1
2. EU countries	3,240.3	87,903	27	11,354	12.9
3. Total Europe	10,200	135,945	13	16,717	12.3

Water use in European agriculture amounts to about 30 percent of abstracted water and about 55 percent of all consumed water.

3.4. *Tourism*

Tourism, in forty years of development, has become very important in national economies, with the participation of about 1.2 percent (average) of GDP in OECD countries. In Croatia, the share of tourism in GDP in 1996 was 2.53 percent, and in 1998, 2.47 percent (SLJH - 2000). Tourism results in seasonal growth of population, often in periods with minimum or low recharging of water resources. This causes pressure on water resources, through increased water consumption. Another property of tourism is considerable seasonal variation, with maximum in holiday times, and minimum in the remaining part of the year. Water consumption in tourism is approximately double of that of the local population. Croatia had the maximum number of tourists in 1987 and 1988 (10.4 million arrivals per annum). In 1990, it was 8.5 million; in 1995, 2.4 million; in 1998, 5.5 million; and in 1999, 4.8 million of tourist arrivals. The number of tourists in EU is the highest in France (61 million arrivals per annum), followed by Italy (52 million), and Spain (43 million).

Water consumption issues are followed by problems of waste water. The largest part of water is not consumed, but returns after use as waste water, treated or untreated, into the sea or rivers. If water is not treated, the problems of environmental pollution occur.

4. Pressures of water resources

4.1. *Water abstraction*

Analysing and comparing the data on water abstraction and water use, one may notice that the data from different sources often do not match. This statement is equally valid for Croatia and for other European countries. In most cases, the differences are caused by different definitions of the analysed case. For example, the definition of water requirements for industry may range from water quantity in the industrial sector to inclusion, along with industrial requirements, water use for cooling of power plants and water for power generation. Table 4 presents the data on total abstracted water quantities. The basic source for water abstraction is surface water (about 75 percent of all abstracted water for all purposes). Ground water is used 25 percent, with only minor quantities of water obtained by desalination of sea/brackish water, and recycling of treated waste water (ETC/IW, 1997).

Table 4. Total abstracted water quantities

Country	*Population (000)*	*Total abstracted water (mill.cu.m./annum)*			*Abstracted water per capita (cu.m./annum) from ETC-IW data*
		DOBRIŠ 1986/83	*OECD 1995*	*ETC-IW 1995*	
1. Croatia Source: SLJH-2000	4,784	1,403 (for 1998)	-	-	293
2. 15 EU countries	372,752	251,938	226,772	245,761	659
3. Europe, continent	680,000	480,000	-	-	700 (Dobriš)

In countries with sufficient number of aquifers, over 75 percent of water for public water supply is abstracted from ground water. Ground water, in general, is of better quality than surface water, and ground water resources are exploited to a higher extent than surface water. Such practice leads to excessive abstraction of ground water resources and to lowering of ground water level. This in turn leads to degradation of the sources of surface watercourses, destruction of wetlands, and in the case of coastal waters, penetration of salt water into aquifers (IWSA, 1997).

Table 5. Share of ground water in total abstracted water and in public water supply

Country	*Abrstracted ground water (%)*	*Public water supply*	
		Ground water (%)	*Surface water (%)*
1. Croatia	42	86	14
2. 15 EU countries	25	62	38

Table 6. Water use by sectors

Country	*Total abstracted water (million cu.m/annum)*	*Urban consumption (%)*	*Industry (%)*	*Agriculture (%)*	*Power (%)*
1. Croatia (SLJH 2000)	1,403	38	60	2	-
2. 15 EU countries	251,938	14	18	30	38
3. Europe, continent	480,00	19	53	28	-

Abstracted water quantities in EU countries are used for municipal purposes in 14 percent of cases, in agriculture (30 percent), industry (18 percent, cooling water excluded), as cooling water and in power generation (38 percent). The falling trend may be attributed to changes in management strategy, which turns towards water demand management, reduction of leakages, more efficient water use, and use of recycled water. The share of municipal water requirements in all abstracted quantities in Croatia is 38 percent, the average for 15 EU countries being 14.1 percent. In a major number of countries, municipal water requirements include, along with household demands, industrial requirements, agriculture, small-scale industry, public services, and recreation requirements. It is often impossible to obtain separate statistic data. The share of household demand in total requirements is between 30 and 60 percent. In Croatia, in 1998, the share of households is 58 percent, and other activities 42 percent of municipal water demands (Hrvatske vode,...). Water use in households and small-scale industries in litres per capita per day shows great differences. The quantities range from 132 to 250 l/cap/day in EU, in Eastern Europe 150 to 300 l/cap/day. In Croatia, the consumption in 1998 was 240 l/cap/day.

For industrial use, excluding cooling water, in 15 EU countries, about 10.4 percent of all abstracted water is consumed. According to data from SLJH-2000 the quantity for Croatia is 60 percent. This figure is subject to dispute. Probably this quantity includes cooling water as well. Observing only water quantity provided from public water supply, the figure of 13.1 percent of all abstracted water is obtained.

4.2. *Climate changes*

Estimates of climate changes indicate that air temperatures will increase by 1°C to 3.5°C in 2010. which, with increased rainfall in Northern Europe and its decrease in Southern Europe, may lead to reduction of renewable water resources in Southern Europe. Increased temperature may result in earlier snow melting, causing winter runoff and reduced runoff in spring and summer. The variation of drought risk and intensity is the most serious adverse impact of climate change on water resources. Climate changes might have a considerable impact on the flood regime (WRI, 1992).

5. Status of water resources

5.1. *Water resources*

Fresh water resources are continuously recharged by natural processes in the hydrological cycle. Precipitation on land surface on Earth provides more than 110, 000 cu. km of water per annum. Approximately 65 percent of precipitation returns to the atmosphere through evapotranspiration. The remaining part is runoff. This part recharges the aquifers

and supplies water to watercourses and lakes (Shiklomanov, 1991). The average runoff determined in Europe is about 3, 100 cu. km per annum or, as an equivalent, 4, 560 cu. m per capita per annum. The quantities of available water in Europe vary depending on annual runoff, ranging from over 3, 000 mm in a part of Norway to less than 25 mm in southeastern Spain (WMO, 1987). Transboundary runoff makes a considerable part of the resources in many countries. In Hungary, for instance, it is 95 percent of all resources. The quantity of renewable water resources is shown in Table 7. Total renewable resources, available to a country, may be perceived as resources from its own territory (endogenous resources) increased by water coming from upstream countries (exogenous resources) (OECD, 1996) and (Gustard et al., 1997).

Table 7. Quantity of renewable endogenous and exogenous water resources

Country	*Renewable resources (million cu. m/annum)*	*Renewable resources per capita (cu. m/annum)*
1. Croatia	169,000	35,300
2. 15 EU countries	1,452,000	3,900
3. Europe, continent	3,000,000	3,560

The highest water demand is present in areas with high concentration of population. Water demand n Europe has grown from 100 cu. km per annum in 1950, through 551 cu. km in 1990, to 660 cu. km per annum in 2000.

5.2. *Quality of water resources*

Analyses of the volume of abstracted water and the volume of resource often neglect the fact that water can meet human needs, as well as the environmental needs, only if its quality corresponds to the intended purpose. As traditionally in the majority of countries attention is paid mainly to water quantity issues, the water quality issue will become increasingly important for planning and management of water resources and infrastructure (WRI, 1992). The major types of use and functions of water resources include: drinking water supply, water for bathing and recreation, water for industry, fishery, irrigation, livestock farming, and environmental purposes. The required water quality varies depending on the use or purpose. Table 8 gives some indices of water quality depending on the use and purpose.

Table 8. Relations between water quality indices and the use and purpose

Indicators	*Ecologic function*	*Use*				
		Drinking water	*Bathing and recreation*	*Irrig-ation*	*Livest-ock*	*Fish-ponds*
Organic matter	+	+				+
Nitrates	+	+			+	+
Phosphorus	+					+
Suspensions	+	+	+			+
Colour		+				
Temperature	+					
Mineralization		+		+	+	+
Micro-organisms		+	+	+	+	
Phytoplankton	+	+				+
Inorganic micro-pollutants	+	+		+	+	+
Pesticides	+	+		+	+	+
Organic micro-pollutants	+	+				

Marks: +: function and use depending on indicator
empty: function and use not depending on indicator

6. Impact on water resources

6.1. *Pressures causing water stress*

We speak about water stress in cases when abstracted water quantities are in discrepancy with available water quantities in a given area. The index of water availability and pressure on water resources is the ratio between the quantity of abstracted water and total renewable resources.

From the data in Chapters 4 and 5, the following ratios were calculated:

- For Croatia, abstracted water quantities in relation to total resources are 0.9 percent; in relation to its own resources 3.3 percent; together with water used for power generation and cooling the result is 19.8 percents of the total resources.
- For Europe (average): total abstracted water makes 15 percent of renewable resources (Gereš, 1998).

Potentially, all countries have sufficient resources to cover their national water demand. The highest water demand is concentrated in areas with high population density. Frequently, urban water demands are higher than the available water resources. Seasonal or multi-annual variations of available water resources may sometimes lead to water stress in areas where, in the long run, there are sufficient water resources. Water resource planners often base their decisions on water use on resources which may be expected in periods of drought or low discharges in rivers. A recommendable indicator for such decisions is the 90 percent discharge (Q90), i.e. the quantity of water that may be used 328 days per annum (90 percent of the time).

6.2. *Drought*

The water demand in Europe has grown from 550 cu. km in 1990 to 660 cu. km in 1999. The occurrence of droughts shows the vulnerability of water resources in relation to variations in the meteorological and hydrological cycle. The expected growth of water demands will result in a conflict between human needs (commercial, social, and political) and environmental requirements. Assessment of droughts is a complex problem. There is no consensus on the definition of drought, except in general terms. The most frequent definition is: *The basic property of drought is reduction of available water in a given time and in a given area*. The drought may be described by a number of indices which may be classified in two groups:

1. environmental indices: hydrometeorological and hydrological indices, directly affecting the hydrological cycle;
2. water resource indices: used to measure the impact of drought on the use of water resources, e.g. impact on water supply for municipal purposes or agriculture, impact on aquifer recharging, water abstraction, impact on water levels (surface and ground), impact on fishery, recreation, etc.

The drought period in Europe lasted from 1988 to 1992, when in most countries the registered rainfall and runoff were lower than multi-annual averages. The impact of drought depends on the combination of the hydrological conditions and pressures on water resources. The highest drought in the early 90's in Europe occurred in areas with highest pressures on resources. These are not necessarily the areas with the highest hydrological drought.

6.3. *Impact of excessive abstraction of ground and surface water*

Excessive abstraction of ground water is defined as the abstraction higher than the quantity of recharge – renewal, resulting in lowering of the ground water level. The effects of excessive ground water abstraction are lower discharges in watercourses, endangered wetlands, and penetration of saltwater into aquifers. Excessive abstraction of surface and/or ground water may result in serious consequences for the related terrestrial and aquatic ecosystems (Kondzewicz, 1997). Water abstraction modifies the natural hydrological regime and discharges in surface waters (rivers, lakes, wetlands). This causes direct impact on the ecological status of the aquatic ecosystem. Low discharges in watercourses may result in

further problems connected with pollution, such as lowering of the dilution capacity, reduction of the oxygen content, and increasing of nitrate and phosphate concentrations which may cause eutrophication problems.

7. Social response and water demand management

Potential social responses related to water resources are described by regulatory instruments: national, EU, and international, and through two major aspects of sustainable water use: management of water demand and water supply infrastructure. The paper does not describe the regulatory – legislative elements.

7.1. *Water demand management*

The goal of sustainable water management is the balance between abstraction of water quantities for public water supply, industrial and agricultural purposes, quantities for recreational and environmental requirements, quantity of waste water, and impact on dispersed water sources. The principle of control is applied, based on permits/concessions, in order to achieve balance between different water demands. Economic instruments are being introduced, such as water abstraction fees and the mechanism of water tariffs for users. When the economic instruments are applied to public water supply, they have the strongest impact on the poorest segments of the society. In order to ensure revenues, the municipal companies must increase the price in case the water consumption is reduced. The general benefit of water consumers to save money by saving water is therefore small. However, in this case it is possible to save the costs for infrastructure (Buckland and Zabel, 1996). In Croatia, water consumption per household is 166.5 cu. m per annum, and it is paid HRK716 per annum, at the overall price of water from public water supply of HRK 4.3 per cu. m. In Euros, this is EUR 99 per annum per household. The price of drinking water is different in European countries. It depends on the area, type of service, etc. In Western Europe, the price ranges from EUR 52 per annum per household in Rome to EUR 287 per annum per household in Brussels. In the countries of Central Europe, the water price is lower, ranging from EUR 20 per annum per household in Bucharest to EUR 59 per annum per household in Prague. If the annual price water per household is considered in relation to gross domestic product (per capita), then the price in Bucharest is 3.5 percent; in Prague 2.3 percent; in Portugal 2.2 percent; etc. In Croatia, the price of water is 1.8 percent of GDP per capita.

7.2. *Infrastructure*

The technical condition of water supply mains and distribution networks has a direct impact on total abstracted water quantity (Gereš, 1995). The efficiency of the network, defined as the ratio of water quantity delivered to the user and abstracted water is: in Croatia 67 percent, in France about 75 percent, in Spain about 80 percent, in Italy about 74 percent, in Austria about 88 percent, in the Czech republic about 70 percent, etc. The estimated leakages from water supply networks (excluding household connections) are: in the United Kingdom 8.4 cu. m/km/day, in Germany 3.7 cu. m/km/day, in Croatia 14.7 cu. m/km/day, etc. Leakages from water supply networks can be reduced in different ways, such as: repair of visible leakages, establishing of leakage control zones, detection and repair of leakages invisible from ground surface, telemetry of flow in the pipes, reduction of pressure, replacement of old pipelines, detection and repair of household connections, reduction of overflow in storages, etc.

Generally it may be said that water consumption grows when there is enough water at a low price. These two concepts are slowly disappearing, particularly in cases of increased resource pollution, drought, and increasing of water tariffs. The purpose of storage reservoirs and flood storages is to abridge uneven distribution of natural water resources in time. Regulation may be seasonal or multi-annual. In Croatia there are 58 storage reservoirs with the total gross capacity of 310 million cu. m (excluding flood storages and multipurpose storages). In the European Union, there are about 3500 major storage reservoirs with the total gross capacity of about 150, 000 million cu. m. The countries with the most storage

reservoirs are Spain, Norway, Sweden, etc. In Spain, there are 849 storage reservoirs, in France 521, and in the United Kingdom 517 storage reservoirs.

Recycling of wastewater is growing in EU countries. Desalination of sea or brackish water is in the initial phase. This procedure is considered in the areas without fresh water. The total quantity of desalinated water in Croatia and in Europe is very small.

8. Conclusions

1. In Croatia, water is used for urban purposes 38 percent, in industry 60 percent, in agriculture 2 percent, power generation not included. In Europe, abstracted water is used as follows: for urban purposes 14 percent, industry 10 percent, agriculture 30 percent, for cooling and power generation 32 percent, and for other purposes 14 percent.
2. In the 80's and 90's, water consumption in industry is reducing as a consequence of economic recession. Water consumption is reduced also due to technological improvements of equipment.
3. Agriculture is one of the largest driving forces and pressures affecting the water resources. In Europe, about 30 percent of abstracted water is used in agriculture, and in Croatia only 2 percent, because irrigation is not developed.
4. Water consumption in tourism is typically seasonal, coinciding with limited water resources. Water consumption by tourists is approximately double of that of regular users.
5. Forecasts of climate changes indicate the increase of temperatures by 1°C to 3.5°C and reduction of rainfall by 10 percent. This could result in reduction of renewable water resources by 40 to 70 percent.
6. The water stress is generally connected with excessive water abstraction in relation to the available resources. Excessive use of surface and ground water has a serious impact on related terrestrial and aquatic ecosystems.
7. Economic instruments are essential for achieving of sustainable water management. The price at which water is sold generally does not reflect the real costs, and the price is not the same for all users. The price of water in Croatia for one household is EUR 99 per annum, or 1.8 percent of GDP per capita. In Europe the prices range from EUR 52 to EUR 287 per annum per household.
8. The efficiency of the water supply network has a direct effect on total abstracted water quantities. In many countries, water leakages from the network are very high. In Croatia, leakage is 14.7 cu. m/km/day, in the United Kingdom 8.4 cu. m/km/day, and in Germany 3.7 cu. m/km/day.

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