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Water Supply and Sewerage System in the Republic of Croatia and the Republic of Slovenia

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Abstract

According to forecasts of various international organizations, it is estimated that by 2040 the Earth will be left with no sufficient quantities of drinking water. Water used for supplying drinking water to the population and industry is obtained from natural resources (i.e., the environment) and is distributed through the water supply system to the consumer. The used, polluted water is returned to the environment through the sewerage system with prior water treatment. During the distribution of drinking water through the water supply system, water losses occur. Such lost water does not reach the end consumers and is not even charged by the water supply company. These interconnected processes of obtaining water used for water supply and of returning polluted water to water resources, directly affect the changes in the quantity or quality of water, as well as the local environment and the local population, and, of course, the Earth in general. This paper will analyze statistical data on water supply (the total amount of water intake, distributed water, water losses, length of the water supply network, the number of water supply connections) and sewerage (total amount of wastewaters, length of sewerage network, number of sewerage connections) in the Republic of Croatia and the Republic of Slovenia. The interdependence of these elements will be presented through correlation coefficients.

Key words

Correlation, Sewerage system, Statistics, Water supply

1. INTRODUCTION

Water covers more than 70% of the Earth's surface. However, 97% of water is salty, 2% is trapped in glaciers, and remains only 1% of fresh drinking water. The role of water is multifaceted: it is a crucial necessity, a habitat for plant and animal species, a local and global resource, a transport corridor and a climate regulator. But for the last two centuries water has become the ultimate destination for many pollutants released into the environment.

We collect water for water supply from natural sources; we use it, and return wastewater back to nature. The characteristic feature of today's world is that the heavily polluted wastewater is increasing and the quality water supply is decreasing. In addition to high water pollution levels, losses occurring in the water supply system have a major impact on water supply. The causes of water losses in the water supply system may be different, e.g. the age of the system, pipe porosity, poor system management, illegal water connections to the system, failures and pipe breaks, system flushing. Such lost water does not reach the end consumers and is not even charged by the

water supply company. All of this is due to the “water crisis”, which means that a large part of the population on Earth has no access to drinking water or the basic hygienic living conditions. According to the forecasts of various international organizations, it is estimated that by 2040 Earth will be left with no sufficient quantities of drinking water.

Water supply and sewerage are two cyclically connected infrastructures, as can be seen in Figure 1.

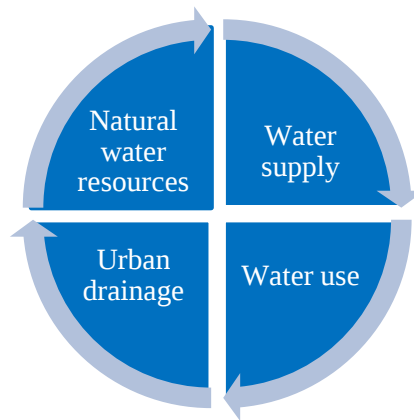


Figure 1. Connection of water supply and drainage

2. STUDY AREA

2.1. Republic of Croatia

The Republic of Croatia is situated in South-Eastern Europe, on the crossroads of Central Europe and the Mediterranean, stretching over 56,594 km² with the interior sea water and territorial sea area of 31,479 km² [1], [2], [3]. There are five neighbouring countries: Bosnia and Herzegovina, Slovenia, Hungary, Serbia and Montenegro [3]. According to the Köppen's classification, most of the Republic of Croatia has a moderately warm, rainy climate characterised by a mean monthly temperature ranging between -3 °C and +18 °C in the coldest month [2]. The capital of Croatia is Zagreb. Croatia has 4,456,096 inhabitants (according to 2011 census) [4]. Croatia has a total of 128 towns/cities and 6,757 settlements [2]. Also, there are in Croatia 1,620,002 house numbers and 53,096 streets [5].

2.2. Republic of Slovenia

The Republic of Slovenia is situated in Central and South-Eastern Europe, bordering Austria, Croatia, Hungary and Italy. The country has an area of approximately 20,271 km² and has a population of 2,094,060 [6], [7], [8]. According to the Köppen climate classification, most of Slovenia has a warm-temperate humid climate with the warmest month having a mean temperature below 22 °C and four or more months having a mean temperature above 10 °C. The climate of some coastal areas of Slovenia has a warm-temperate Mediterranean climate with the warmest month mean temperature being above 22 °C and humid conditions all year round [9]. The capital of Slovenia is Ljubljana. Slovenia has a total of 6,036 settlements [10]. In Slovenia, there are 558,160 house numbers and 10,400 streets [11].



Figure 2. Map of Republic of Croatia (left) and map of Republic of Slovenia (right) [12],[13]

For the purpose of clarity and easy comparison of the two analyzed countries, some of the aforementioned data are presented in Table 1.

Table 1. Basic information about Croatia and Slovenia [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11]

Parameter	Croatia	Slovenia
Land area [km ²]	56,594	20,271
Population	4,456,096	2,094,060
Number of settlements	6,757	6,036
House numbers	1,620,002	558,160
Number of streets	53,096	10,400
Capital	Zagreb	Ljubljana
Number of neighbouring countries	(5+1 on sea)	4
Official script	Latin	Latin
Currency	Croatian Kuna (HRK)	Euro (EUR)
International telephone code	+ 385	+ 386

3. WATER SUPPLY AND SEWERAGE SYSTEM IN CROATIA

3.1. Water Supply

Croatia is a water-rich country split between two river basin districts, the Danube basin and the Adriatic basin. With around 24,495 m³ of renewable water per capita per year, Croatia is a water-rich country. Surface water quality is, however, a concern, particularly with respect to nutrient pollution in the Danube basin. Water supply comes mainly from groundwater (96%). Surface water provides 4% of overall drinking water supply. Most rivers flow into the Danube or one of its tributaries. Local governments are responsible for water and sanitation services and provide them through 156 public utility companies (140 for water and sanitation service and only 16 for sanitation service). Service quality in Croatia is generally very good by regional standards. Water service is continuous, and drinking water quality is mostly in compliance with national and European standards. The water supply network, which is 4 times as long as the wastewater network, is aging - most of it was installed more than 50 years ago - and its performance could be improved, since the leakage rate is as much as 40% [14].

Table 2. Basic characteristics of the water supply system (part of the analyzed data) [15]

Parameter	Year				
	2014	2015	2016	2017	2018
Total abstracted water (in 1000 m ³)	501188	508541	524063	505029	503503
Total distributed water (in 1000 m ³)	307969	314906	307953	292908	302856
Total water losses (in 1000 m ³)	193219	193635	216110	212121	200647
Total length of water supply network (km)	42609	43104	44627	45603	45676
Number of water connections	1247887	1245376	1245376	1245818	1257773

3.2. Sewerage System

Croatia has traditionally had a high level of service, with near-total access to piped water (99%) and flush toilets (95%). Croatian wastewater infrastructure needs upgrading. Among the 141 wastewater treatment facilities, 46% are equipped with preliminary and primary treatments, 51% with secondary treatment, and only 3% with tertiary treatment [14]. The typical sewerage system is mixed (faecal and precipitation waters together). Only a few smaller cities and residential districts of bigger towns have separate or split sewerage systems (faecal and precipitation waters are split) [16].

Table 3. Basic characteristics of the sewerage system (part of the analyzed data) [15]

Parameter	Year				
	2014	2015	2016	2017	2018
Discharge of wastewater (in 1000 m ³)	333353	327872	334790	312022	335807
Total length of sewerage network (km)	9649	10493	10885	12047	12448
Number of sewerage connections	521882	521882	555147	568842	584243

4. WATER SUPPLY AND SEWERAGE SYSTEM IN SLOVENIA

4.1. Water Supply

Slovenia has good-quality and sufficient water resources. Eighty-one percent of the Slovenian territory belongs to the Black Sea basin, and the rest is part of the Adriatic Sea basin. With 15,411 m³ per capita per year, there are sufficient quantities of water on average in Slovenia, and most of it is in a good ecological state. However, agriculture has had a severe impact on groundwater quality, and there is a concern about the decreasing groundwater level in certain areas due to overabstraction. Drinking water supply relies almost exclusively on groundwater. Surface water is predominantly used for the production of electric energy in hydroelectric power stations, while groundwater provides 97% of the raw water for potable public supply. Local government units provide water and sanitation services through 98 utilities. Drinking water quality in Slovenia improved during 2004 to 2013 for both microbiological and chemical parameters. The compliance rate has steadily increased over the last decade to 92% in 2013. One-fourth of the Slovenian water network was installed before 1920. From 2000 to 2010, the rehabilitation of water supply systems was boosted by EU grants and funding specifically dedicated to water infrastructure improvement [17].

Table 4. Basic characteristics of the water supply system (part of the analyzed data) [18]

Parameter	Year				
	2014	2015	2016	2017	2018
Total abstracted water (in 1000 m ³)	163095	164404	161821	169385	170718
Total distributed water (in 1000 m ³)	117205	117886	116698	122559	121162
Total water losses (in 1000 m ³)	45890	46517	45123	46827	49556
Total length of water supply network (km)	24017	30923	31165	32519	32360
Number of water connections	458305	439736	433305	444041	454487

4.2. Sewerage System

Slovenians have full access to water services. Ninety-nine percent of the Slovenian population has access to piped water and flush toilets. Among the 486 water treatment plants, 72% rely on chlorine disinfection and 13% on mechanical and chemical treatment [17].

Table 5. Basic characteristics of the sewerage system (part of the analyzed data) [19]

Parameter	Year				
	2014	2015	2016	2017	2018
Discharge of wastewater (in 1000 m ³)	183285	162540	200653	217726	230638
Total length of sewerage network (km)	8842	9638	8950	9664	9972
Number of sewerage connections	266918	284120	268039	289680	296648

5. RESULTS AND DISCUSSION

In this part of the paper, data on the water supply and sewerage system for the Republic of Croatia and the Republic of Slovenia for a 10-year period was analyzed. The period analyzed is from 2009 to 2018.

Table 6 shows some basic data on the water supply system and sewerage system for both countries.

Table 6. Basic data of the water supply and sewerage system

Parameter	Unit	Croatia	Slovenia
Average water losses per capita	m ³	51.01	23.67
Average water consumption per capita	m ³	78.47	57.86
Average abstracted water per capita	m ³	129.48	81.52
Average amount of wastewater per capita	m ³	67.95	110.14
Average water losses per one km of water mains	m ³	4392.83	1531.40
Average wastewater amount per one sewerage connection	m ³	574.77	777.48
Average water consumption per one water connection	m ³	240.79	266.60
Water supply network density	km/km ²	0.807	1.60
Sewerage network density	km/km ²	0.220	0.50

Programs MS Excel® and TIBCO Statistica™ were used to process the data. All the tables shown below are given in their original form and obtained from the TIBCO Statistica™ software package used for statistical data processing while for diagrams is used MS Excel.

Table 7 shows the descriptive statistics for the data on the water supply and sewerage system of the Republic of Croatia, while Table 8 shows the descriptive statistics for the data on the water supply and sewerage system of the Republic of Slovenia. Eight variables are observed as follows: Discharge of wastewater (m³), Total length of

sewerage network (km), Number of sewerage connections, Total abstracted water (m³), Total distributed water (m³), Total water losses (m³), Total length of water supply network (km) and Number of water connections.

Table 7. Descriptive statistics for the data on the water supply and sewerage system of the Republic of Croatia

Variable	Descriptive Statistics (Croatia.sta)				
	Valid N	Mean	Minimum	Maximum	Std.Dev.
Discharge of wastewater (m ³)	10	324455200	301030000	343544000	14453256
Total length of sewerage network (km)	10	9853	8144	12448	1557
Number of sewerage connections	10	512320	435607	584243	47495
Total abstracted water (m ³)	10	537884400	501188000	576985000	32075086
Total distributed water (m ³)	10	330747900	292908000	365281000	27641139
Total water losses (m ³)	10	207136500	193219000	227293000	10630124
Total length of water supply network (km)	10	43111	41246	45676	1619
Number of water connections	10	1229711	1146088	1257773	33884

Table 8. Descriptive statistics for the data on the water supply and sewerage system of the Republic of Slovenia

Variable	Descriptive Statistics (Slovenia.sta)				
	Valid N	Mean	Minimum	Maximum	Std.Dev.
Discharge of wastewater (m ³)	10	186774700	151465000	230638000	25170598
Total length of sewerage network (km)	10	8620	7215	9972	957
Number of sewerage connections	10	263504	231243	296648	22502
Total abstracted water (m ³)	10	165556400	161731000	170718000	3212054
Total distributed water (m ³)	10	119326800	116698000	122559000	1958004
Total water losses (m ³)	10	46229600	42352000	49556000	2309067
Total length of water supply network (km)	7	27899	21656	32519	4875
Number of water connections	7	450271	433305	466461	11620

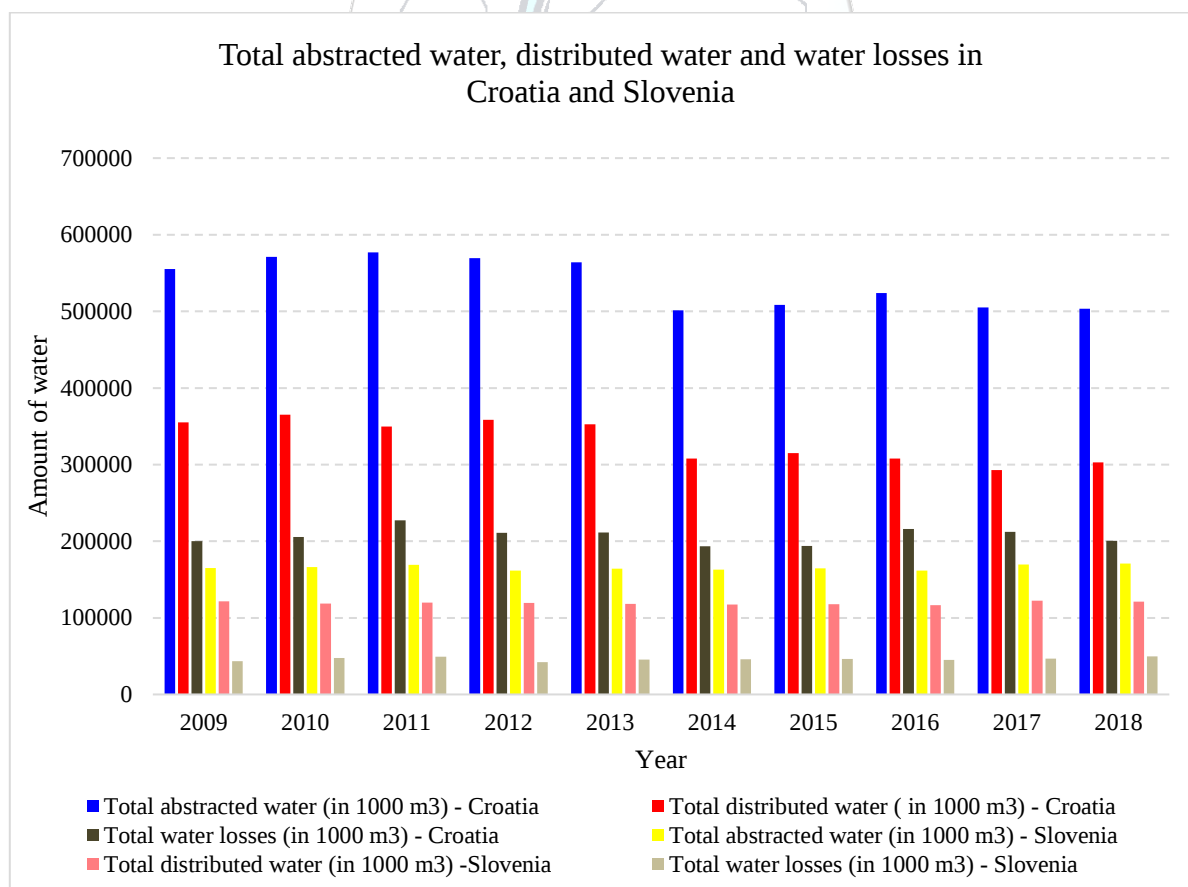


Figure 3. Total abstracted water, total distributed water and total water losses for the Republic of Croatia and Republic of Slovenia for a 10-year period

The following two tables (Tables 9 and 10) show the correlation coefficients for all the eight variables (five variables on the water supply system and three variables on the sewerage system) for the Republic of Croatia.

Table 9. Correlation coefficients for five variables of the data on the water supply of the Republic of Croatia

Variable	Correlations (Croatia) Marked correlations are significant at $p < .05000$ N=10 (Casewise deletion of missing data)				
	Total abstracted water (m3)	Total distributed water (m3)	Total water losses (m3)	Total length of water supply network (km)	Number of water connections
Number of water connections	-0,491906	-0,581819	0,028615	0,638773	1,000000
Total length of water supply network (km)	-0,734558	-0,861877	0,024670	1,000000	0,638773
Total water losses (m3)	0,553988	0,258278	1,000000	0,024670	0,028615
Total distributed water (m3)	0,947360	1,000000	0,258278	-0,861877	-0,581819
Total abstracted water (m3)	1,000000	0,947360	0,553988	-0,734558	-0,491906

Table 9 shows the relationship between the Total Length of water supply network and: Total abstracted water ($r = -0.734558$), Total distributed water ($r = -0.861877$) and Number of water connections ($r = 0.638773$).

Table 10. Correlation coefficients for three variables of the data on the sewerage system of the Republic of Croatia

Variable	Correlations (Croatia) Marked correlations are significant at $p < .05000$ N=10 (Casewise deletion of missing data)		
	Discharge of wastewater (m3)	Total length of sewerage network (km)	Number of sewerage connections
Discharge of wastewater (m3)	1,000000	0,319136	0,360549
Total length of sewerage network (km)	0,319136	1,000000	0,964483
Number of sewerage connections	0,360549	0,964483	1,000000

Table 10 shows the relationship between the Total length of sewerage network and Number of sewerage connections ($r = 0.964483$).

Tables 11 and 12 show the correlation coefficients for all the eight variables (five variables on the water supply system and three variables on the sewerage system) for the Republic of Slovenia.

Table 11. Correlation coefficients for five variables of the data on the water supply of the Republic of Slovenia

Variable	Correlations (Slovenia) Marked correlations are significant at $p < .05000$ N=7 (Casewise deletion of missing data)				
	Total abstracted water (m3)	Total distributed water (m3)	Total water losses (m3)	Total length of water supply network (km)	Number of water connections
Total abstracted water (m3)	1,000000	0,836563	0,837419	0,634198	-0,066432
Total distributed water (m3)	0,836563	1,000000	0,401109	0,371276	0,172839
Total water losses (m3)	0,837419	0,401109	1,000000	0,689979	-0,283524
Total length of water supply network (km)	0,634198	0,371276	0,689979	1,000000	-0,756905
Number of water connections	-0,066432	0,172839	-0,283524	-0,756905	1,000000

Table 11 shows the relationship between the Total abstracted water and: Total distributed water ($r = 0.836563$) and Total water losses ($r = 0.837419$).

Table 12. Correlation coefficients for three variables of the data on the sewerage system of the Republic of Slovenia

Variable	Correlations (Slovenia) Marked correlations are significant at $p < .05000$ N=10 (Casewise deletion of missing data)		
	Discharge of wastewater (m3)	Total length of sewerage network (km)	Number of sewerage connections
Discharge of wastewater (m3)	1,000000	0,621428	0,650735
Total length of sewerage network (km)	0,621428	1,000000	0,990051
Number of sewerage connections	0,650735	0,990051	1,000000

Table 12 shows the relationship between the Discharge of wastewater and Number of sewerage connections ($r = 0.650735$), and between the Total length of sewerage network and Number of sewerage connections ($r = 0.990051$).

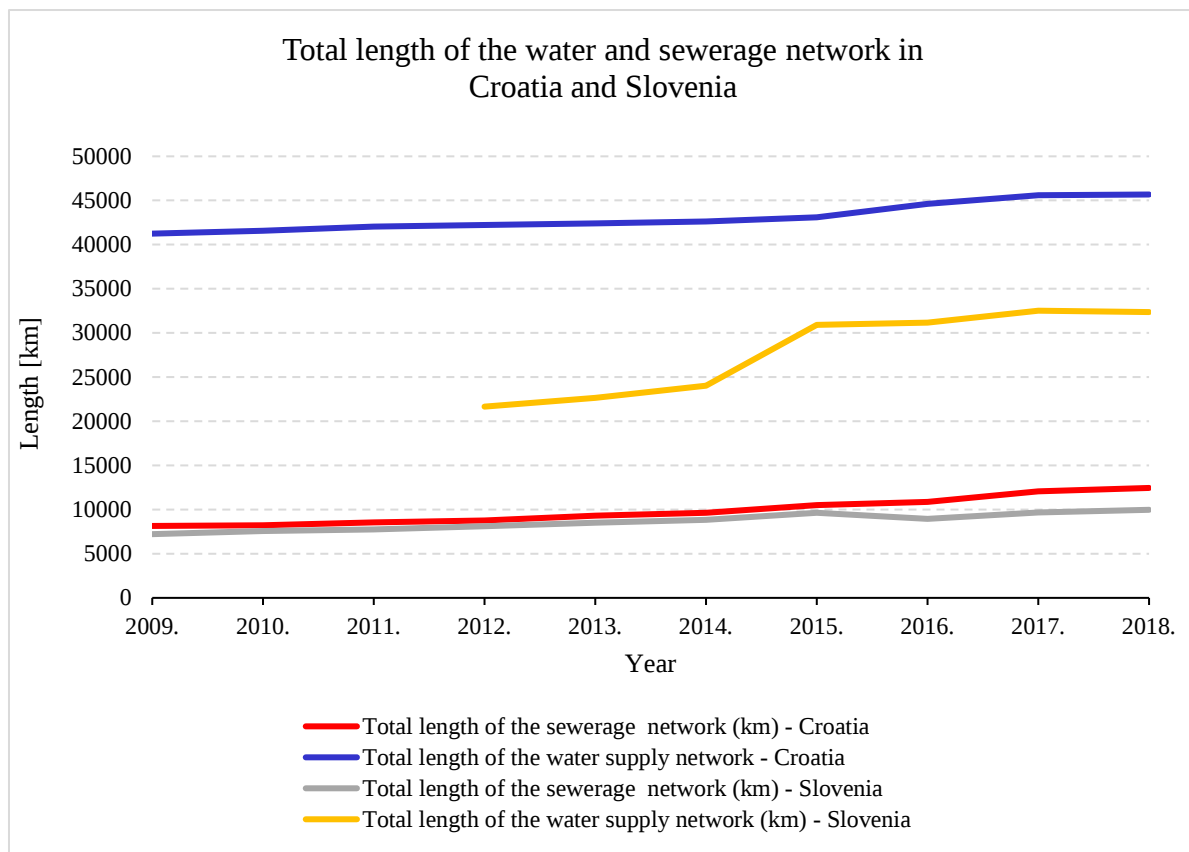


Figure 4. Total length of the water and sewerage network for the Republic of Croatia and Republic of Slovenia for a 10-year period

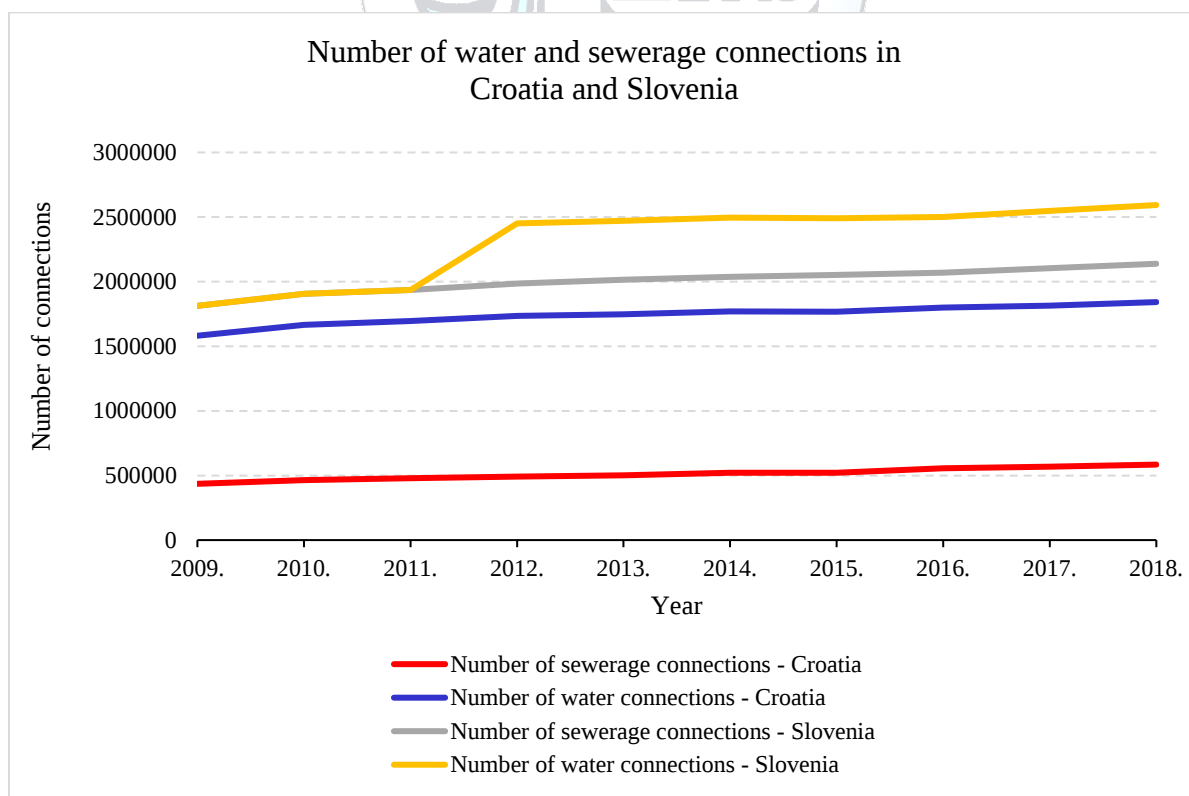


Figure 5. Number of water and sewerage connections for the Republic of Croatia and Republic of Slovenia for a 10-year period

6. CONCLUSIONS

By analyzing the correlation coefficients between individual parameters of water supply and sewerage, it can be concluded that the parameters with a correlation coefficient higher than 0.7 have a good connection or a significant mutual influence. For parameters between which the correlation coefficient is less than 0.7 we can say that the correlation is small or non-existent, i.e. that they do not have mutual influences.

All correlations between the water supply and sewerage system can be used in the development of the model and the calculation of a specific required data if we know some input data. The development of such models is a potential subject of future research. The construction, connection and condition of the water supply and sewerage network are of great importance for the development of each country. The main problems faced by all countries are water losses in the water supply, and the treatment and discharge of wastewater into the environment. Today, we are witnessing declining supplies of drinking water, and large-scale pollution of water and the environment from the discharge of untreated wastewater, and various diffuse sources of pollution. According to the EU Framework Directives (of which Croatia and Slovenia are members) it is necessary to achieve the maximum connection of the population to the water supply and sewerage network, reduce water losses to the limits of permitted losses, build wastewater treatment plants and connect all settlements up to a minimum of 2000 population equivalent, all with the aim of achieving a good water status and a sustainable water management. This paper shows that in Croatia and Slovenia the connection to the water supply and sewerage system is satisfactory. However, it is working on a higher percentage of construction and connection to the networks. Water losses in the water supply system are high in both countries, as a result of the age of the network, inadequate maintenance, failures and damage. In Croatia, an additional problem for water supply and sewerage is a large number of small settlements with less than 500 population equivalent for which it is economically unprofitable to bring sanitary infrastructure. These settlements have water supply from local wells, and wastewater is collected in septic tanks that are water permeable and represent sources of diffuse pollution.

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