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WATER QUALITY OF THE RIVER SUTLA AND POSSIBILITY OF RIVER RESTORATION

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Abstract

The river Sutla (Sotla) forms the border between the Republic of Slovenia and Republic of Croatia. The Sutla Lake (Vonarje reservoir) of 12.4 million m^3 was built and filled in 1980 as drinking water supply and for flood protection. Immediately after filling, the reservoir showed extreme water quality problems, degradation of the water use. Due to high risk for the humans and the environment that has roughly been managed successfully, the reservoir was drained in 1988. Now it operates as a dry retention basin for flood protection. Over the past decade, the area of the Sutla catchment has developed as touristic area. Nowadays, there are many local and regional initiatives to fill the Sutla Lake with water again and to build tourist and recreational facilities. There are also initiatives to use water for irrigation and as a drinking water supply. All of the stated facts indicate an urgent necessity to improve the water quality of the river Sutla and to redefine the Sutla Lake as a multipurpose lake. We propose a conceptual framework for water quality management and design of the mathematical model for the river Sutla water quality with emphasis on the Sutla Lake.

Key words

DPSIR approach; eutrophication; water quality; river restoration

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1 INTRODUCTION

River Sutla (Sotla) forms the border between the Republic of Slovenia and Republic of Croatia. The size of the Sutla river basin is almost 600 km^2. The Sutla lake/Vonarje reservoir of 12.4 million m^3 was built and filled in 1980. The main purpose was drinking water supply for both Slovenian and Croatian settlements and flood protection of downstream areas. Shortly after filling, water in the reservoir became eutrophicated. Besides, other extreme water quality problems have been detected not only in the lake water but also in the river water downstream. Due to high risk for the human and the environment that has hardly been managed successfully, the reservoir was drained in 1988. Lacking a better solution, the reservoir was completely drained in 1988. Now it operates only as a dry retention basin for flood protection. On the edge of natural retention, wetland ecosystem has been developed. For this reason, the natural retention area of the Slovenian side and the area of riverbed Sutla on the Croatian side, are of the Natura 2000 sites.

In the course of the past decade, the area of the Sutla catchment has developed as touristic area. Now, there are many local and regional initiatives to fill the Sutla Lake with water again and develop touristic and recreational facilities along its shore. There are also initiatives to use water for irrigation and as a drinking water supply. Both Slovenia and Croatia, being the new EU Member States, are now faced with the great challenge to achieve not only the good ecological and chemical status of the Sutla Lake and the river Sutla (as directed by Water Framework Directive), but also to achieve good or excellent quality for bathing and protection from adverse effects of water [1]. Furthermore, they also have to deal with tourist, recreational, fishing and irrigation needs at the same time. But firstly, they have to guarantee that emissions from urban areas [2] and agricultural activities in the catchment are reduced and managed accordingly.

Due to implementation of the European industrial and urban waste water treatment legislation and environmental agricultural policy both in Slovenia and Croatia (which became a member State in 2013), emissions from water and risk to water quality in the Sutla Lake are expected to be much lower in the future then in 1980’s. Nevertheless, pollution residuals on the bottom of the lake, pollution caused by more traffic, impact on water environment from fisheries, tourist and recreational facilities, intensified agricultural activities and expected changes of climate patterns do not necessarily support this expectation. Furthermore, the users of the catchment on the Slovenian and Croatian side are a bit different. On the Slovenian side, there is more industry, “industrial” tourism (large congress, thermal and wellness facilities) and larger urban areas. On the Croatian side, the inhabitants are mainly engaged in traditional agriculture. The water uses are less intensive. Waste water collection and treatment depend on settlement patterns and differ in technologies applied.

Slovenia and Croatia, both EU countries, are expected to apply for new development and cohesion funds to develop environmental and other infrastructure in the catchment. It is important that in the water management we take into account two national institutional systems and different economic developments in the past two decades. There are strong cultural ties between local communities on both river sides. Therefore, the challenge to secure good ecological and chemical status of the river Sutla is today even greater that it has been in the past. For this purpose, it is necessary to know the catchment hydrological and hydraulically characteristics, sources of pollution, pollutants' flow, various chemical parameters decomposition patterns and existing aquatic ecology. Only then we might be able to analyse pollutant’s impacts on aquatic ecosystems and quantify water quality parameters under different development scenarios. Knowing these processes is crucial for proposing remediation measures and setting economically sound environmental protection management measures.

To face these challenges authors have developed conceptual water quality management model for the catchment. It should initiate common approach for both countries to control water quality on catchment level and manage aquatic ecosystem to fulfilling environmental goals. This paper describes the model and presents available information on water quality in each country.

2 DESCRIPTION OF STUDY AREA

The river Sutla originates at the altitude of 717 meters below the Macelj hill and flows into the Sava River southeast of Brežice town. The terrain of the catchment area ranges from appr. 1000 meter above sea level to 100 meter above sea level (see Figure 1). It is 91 km long. After 3 km of headwater section, it becomes a national border between Slovenia (right side of the river) and Croatia (left side of the river). At the downstream section, before it flows into the Sava River, the national border is laying on the river Sutla and former course (before the regulation). Its catchment area is 590.6 km^2 large, of which 78% is located in Slovenia, and the rest in Croatia. Valley Sutla is relatively broad. The river's natural flow is meandering, except on the regulated sections. Plain passes on both sides of the flat tertiary hills, with excellent wine growing areas.

The river Sutla is highly skewed, due to larger inflows almost exclusively from the right side (see Figure 1.). Despite the short length on the left side, streams are relatively abundant because of the high proportion of impermeable rock. The most significant two right tributaries are Mestinjščica and Bistrica ob Sotli (or shortly “Bistrica”). Bistrica drains the western and southern part of the Sutla catchment. Its valley is incised into resistant Triassic rocks, so it is relatively narrow and has torrential character. In Figure 1 hydrography and relief are shown.

The only lake that existed shortly on the river Sutla was the Sutla Lake, the artificial lake behind the Vonarje dam. Area of the former lake (reservoir), which was emptied in 1988 due to eutrophication, was 1.95 km^2, and is currently being used as retention in case of high water. Capacity is 12.4 million m^3, out of which 3.7 million m^3 is required for 100-year flood protection.

The average annual precipitation in the Sutla river catchment is 1200 mm, and evapotranspiration is about 650 mm. The river Sutla has the Pannonian flow regime with two identical peaks, one in early spring and the other in late autumn. Low flows occur in summer and winter. August has the lowest discharge.

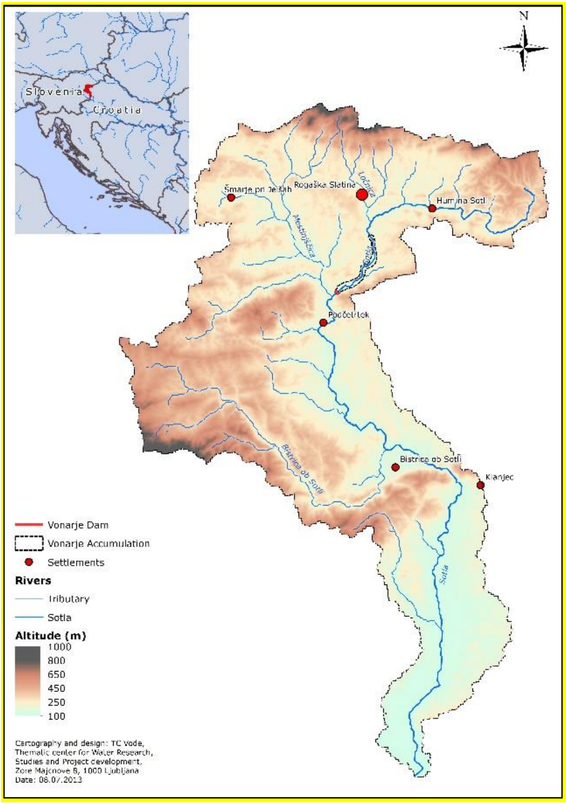


Fig. 1: The Sutla River Basin. The Slovenian part of the catchment lies on the right side of the river (western part). The Croatian part of the catchment lies on the left side of the river (eastern part).

3 CONCEPT OF WATER QUALITY MANAGEMENT

The model for the river Sutla and the Sutla Lake applies a life-cycle concept with the DPSIR – Driving Forces- Pressures-State-Impact-Response framework approach. Some authors, [1],[3],[4], [5], have had good experience and results in using DPSIR framework approach in integrated river basin management according to the requirements of the Water Framework Directive.

3.1 DPSIR Framework Approach

Primary driving forces are the need for shelter, food and water. Some of the secondary driving forces are the need for mobility, entertainment and culture. A driving force for the industrial sector would be the need to be profitable and low costs production, while a driving force for a nation would be the need to keep unemployment levels low. Driving forces lead to human activities that exert pressures on the environment, as a result of production or consumption processes, which can be divided into three main types a) excessive use of environmental resources, b) changes in land use, and c) direct or indirect emissions (of chemicals, waste, radiation, noise) to air, water and soil. This may pose hazard to human health and change natural state of environment compartments (air, water, soil, biodiversity). The state of environment is described with physical, chemical and biological conditions. The changes in the physical, chemical or biological state of the environment determine the quality of ecosystems and the welfare of human beings. In other words, changes may have the impact on the functioning of ecosystems, their life-supporting abilities, and ultimately, on human health and on the economic and social performance of society.

European Environmental Agency (EEA) regularly prepares integrated environmental state assessments for Europe, using the DSPIR approach. The aim of assessments is to inform public about the present and most probably future state of environment and impacts of pollution and other pressures to natural systems in Europe. The aim is also to inform national governmental and non-governmental organisations about the environmental issues and to offer sound basis for environmental policy on the European level [6]. According to the DPSIR framework approach there is a chain of causal links starting with '*driving forces*' („**D**") (economic sectors, human activities) through '*pressures*' („**P**") (emissions, waste, structural interventions and changes of natural systems) to '*states*' („**S**") (physical, chemical and biological) and '*impacts*' („**I**") on ecosystems, human health and functions, eventually leading to political '*responses*' („**R**") (policy prioritisation, target setting, protection, setting limits). Describing the causal chain from driving forces to impacts and responses is a complex task, and tends to be broken down into sub-tasks, e.g. by considering the pressure-state relationship. The DPSIR framework is also used as an analytical tool for assessing and modelling water issues. A DPSIR framework for water is shown in Figure 2.

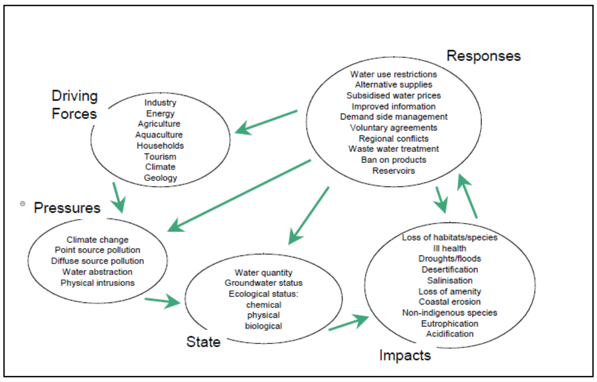


Fig. 2: A DPSIR framework for water environment LIFE-CYCLE ASSESSMENT

Many of the pressures and the underlying driving forces are common to all or a number of the issues. For example, agriculture is a significant driving force in terms of ecological quality of water, water pollution by nutrients and hazardous substances. Energy sector supports (drives) use of water energy and invests a lot into building hydropower plants on rivers. Dams and accumulation of water, even being "stopped" for a short period of time, cause high physical and hydrological (water flow dynamics) pressures to river ecosystems and in the end also a deterioration of river ecological quality. Expanding urbanisation and intensifying industrial and socio-economic-financial service activities increase demands for water supply. Urbanisation is identified as „driving force", water pumping is identified as „pressure to water resources". As a consequence, ecological quality of river deteriorates due to less water in river (water quantity problem).

Driving forces, pressures, state, impacts and responses elements for a chosen (analysed) environmental issue are operationalised by a set of indicators and indexes. The issue that we tackle on the river Sutla is eutrophication and organic pollution as we explain in the following chapter.

3.2 Organic pollution and eutrophication

The effects on the aquatic environment of organic pollution, caused by discharges from waste water treatment plants, industrial effluents and agricultural run-off, include reduced river water chemical and biological quality, as well as impaired biodiversity of aquatic communities and microbiological water quality. Increased industrial and agricultural production, coupled with more of the population being connected to sewerage systems will result in increases in discharges of organic waste and nutrients into surface water. In severe cases of eutrophication, massive blooms of planktonic algae occur. Some blooms are toxic. As dead algae decompose, the oxygen in the water is used up; bottom-dwelling animals die and fish either die or leave the affected area. Increased nutrient concentrations can also lead to changes in the aquatic vegetation. The unbalanced ecosystem and changed chemical composition make the water body unsuitable for recreational and other uses such as fish farming, and the water becomes unacceptable for human consumption. The main source of nitrogen pollution is run-off from agricultural land, whereas most phosphorus pollution comes from households and industry.

4 METHODOLOGY FOR WATER QUALITY MODELLING OF THE SUTLA RIVER

Methodology for water quality modelling of the river Sutla is built within the DPSIR framework approach as presented in the previous chapter. For each DPSIR module specific datasets and/or indicators should be developed as presented in Table 1. For each cluster authors have collected all available data for the longest period possible. The sources are results from national monitoring systems, statistical census and registers. When as much as possible data are collected, data on pressures and states are interpreted. Authors have focused our research on eutrophication and organic pollution.

Data on population and settlements are collected from the Censuses of Slovenia [7] and Croatia [8]. Land use is defined from Corina Land Cover Data sets prepared and hosted at European Environment Agency (EEA) [1][9]. Data and information on waste water collection and treatment in Slovenian part of the Sutla river are obtained from Slovenian Agency for Environment [10], [11] and Croatian Water Management agency, Hrvatske vode [12].

State of water - water quality in Croatia has been carried out on the different regulations, depending on the time period for which they are valid. For the period from 1980-2000 “Regulation on Water Classification NN 15/81”[13], period from 2000-2010 “Regulation on Water Classification NN 107/95” [14] and period from 2010-2012 “Regulation on water quality standards NN” [15]. There are five classes used for five different clusters of parameters: physical – chemical, oxygen regime, nutrients, microbiological parameters and biological parameters. Assessment of water status in Slovenia has been carried out with the use of “Regulation on Water Classification NN 15/81” [13], until joining the European Union when they started using the “Rules on the monitoring of surface waters (Official Gazette of RS, No. 10/09)” [16].

Tab. 1: Dataset and/or indicators for water quality model based on DPSIR approach [3], [4], [5]

Driving Forces (Drivers)	**Pressures**	**State**	**Impact**	**Response**
Urbanization	Extent of urban &semi urban Areas; quantity of waste water produced; sewerage systems by location and capacities; number of landfills and their capacities; level and efficiency of waste water treatment; emissions to water (concentrations and	Concentration of oxygen demanding substances in water (BOD, Ammonium); nutrients in water (nitrate and orthophosphate concentration in rivers; total phosphorus in lakes); Amount of water abstracted from springs, rivers, groundwater, lakes; number and size of dams	Eutrophication, decline in oxygen concentration in water; decline of “naturalness“ of water courses (level of changed state from natural- rate of change of morphologically-hydrological elements); habitat loss; sediment production and land erosion (change in yearly quantities; changes in number of erosion and deposition zones in catchment..);	Drinking water supply development programmes; water protection zones; waste water collection and treatment; programme of measures and setting limits for concentration of chemical parameters to be emitted into environment (specifically adapted for designated areas and size of agglomerations); control

	loads by location of effluents)	and artificial water bodies; regulation length		and supervision of efficiency of WWTPs)
Agriculture	Application of fertilizers and herbicides (pesticide) on agricultural land (amount used and surface applied with); livestock (quantity of slurry and manure produced and released into environment); irrigation and drainage of water (number, extent, capacities and efficiency of irrigation and drainage systems);	concentration of chlorophyll-a in lakes, nitrogen and phosphorus concentrations in water; suspended sediments concentration; low and high water flow characteristics changes; soil saltation; soil water parameters changes;	eutrophication, habitat destruction, algae bloom, sediment production and land erosion; low and high water flow characteristics changes due drainage and irrigation (prolongation of length of low flow periods in river downstream); infiltration capacities of soil changes; soil chemical and microbiological deterioration (in indicators physical and chemical parameters are used to describe changes/impact);	Agro – environmental policies: protection zone, financial support for organic and ecological food production; management plans for lower diffuse pollution loads; efficient organic and artificial fertilizer use; control of manure and slurry storage and re-use;
Industrial development	Effluents of dangerous substances (quantity of emitted waste water with certain concentrations; loads of specific substance)	quantity of emitted industrial waste water; concentrations of dangerous substances; loads of substances;	Bad chemical water quality; ecotoxicological impacts to biota; habitat loss; decrease in population size for aquatic biota; species extinction; soil erosion;	Control of emissions, Setting limits of concentrations; industrial waste water treatment; new technologies; best available technologies; protection zones...
Tourism, Recreation, promotion of human health	Urbanization, waste generation, soil sealing; high demand for water; physical changes of natural systems (building on shores, recreational facilities constructions ..): indicator are sizes, extent , number of new facilities, number of tourists and visitors per season, year etc..)	Quantity of waste production; number of new waste disposal sites; Length of built-up shores; changed morphological status; changes of groundwater level and temperature due pumping and emitting of basin and spa waters; landscape fragmentation indicators; functional changes of aquatic ecosystems;	Deterioration and alteration of structural and functional characteristics of aquatic ecosystems; Loss of biodiversity; forest cut (by area, by altitude, by vicinity of facilities; wetland drying (extent, drainage, built up percentage..); water quality deterioration (indicators for water quality); water flow dynamic change (length of low water flow; high water duration and frequency); sediment production and land erosion (by quantity, location, areal size);	Zoning of land use; mitigation measures; protection zones; Integrated Management Plans;
Need for nature protection, climate change adaptation	Demands for endangered species protection and conservation; demand for protection of natural systems („no go areas“); demand for floods and droughts mitigation;	Number and size of protected sites by law or conventions; Biodiversity and conservation status (number of species and population size by functional group; conservation status for each species listed.); flooding areas; flood and drought frequencies;	Change in biodiversity; Flood risk; drought risk; flood and drought damages;	Measures for species and habitats protection and conservation; evaluation of ecosystem goods & services; public participation; monitoring; designated areas for protection of habitats and endangered and vulnerable species;

5 RESULTS AND DISCUSSION

5.1 Driving forces and pressures indicators

Most of the population lives in small rural settlements. On the Croatian side of the Sutla river population lives in 67 smaller settlements with almost 17,000 inhabitants in total. Administratively they are organized in eight counties. On the Slovenian side of the river, there are 84 settlements in four counties with 36.200 inhabitants in total. The population density on the Slovenian side of the Sutla is 82 inhabitants per km^2, which is almost 20% less then Slovenian average (100 inhabitants per km^2). The population density on the Croatian side of the river is 120 inhabitants per km^2, which is more than half of the Croatian average (78 inhabitants per km^2). Only one settlement in the catchment has more than 2000 inhabitants, Rogaška Slatina (see Table 2). Agriculture is well developed in the area, though it is not intensive. Agricultural land, 63% of all land, forest and shrubs 36%, and other built-up areas account for 1% of the total. Industry and crafts have developed in larger settlements such are

Rogaška Slatina and Šmarje pri Jelšah. Structured information of driving forces and pressures are presented in Table 2.

Tab. 2: Driving Forces/Pressures on the Slovenian and Croatian side of the Sutla river catchment area [5], [6], [7], [8], [9], [12], [17], [18], [19], [20], [21], [22], [23]

<table>
<tr><th></th><th>Catchment on the right side of the Sutla river, Slovenian part</th><th>Catchment on the left side of the Sutla river, Croatian part</th></tr>
<tr><td>Surface of the catchment area</td><td>459,9 km^2 (78% of the whole)</td><td>130,7 km^2 (22% of the whole)</td></tr>
<tr><td>Driving forces:</td><td>Tourism and recreation (wellness, spa, one one-day), protection of cultural and natural heritage (park, protected monuments), traffic, agriculture, industry</td><td>Agriculture, protection of cultural and natural heritage, traffic</td></tr>
<tr><td>Urbanisation:
Number of settlements by range of number of inhabitants</td><td><table>
<tr><th colspan="2">Number of :</th></tr>
<tr><td>inhabitants</td><td>settlements</td></tr>
<tr><td><100</td><td>33</td></tr>
<tr><td>101-500</td><td>47</td></tr>
<tr><td>501-1000</td><td>1</td></tr>
<tr><td>1001-1500</td><td>0</td></tr>
<tr><td>>1500</td><td>3</td></tr>
<tr><td>Total</td><td>84</td></tr>
</table></td><td><table>
<tr><th colspan="2">Number of:</th></tr>
<tr><td>inhabitants</td><td>settlements</td></tr>
<tr><td><100</td><td>21</td></tr>
<tr><td>101-500</td><td>41</td></tr>
<tr><td>501-1000</td><td>3</td></tr>
<tr><td>1001-1500</td><td>1</td></tr>
<tr><td>>1500</td><td>1</td></tr>
<tr><td>total</td><td>67</td></tr>
</table></td></tr>
<tr><td>Two largest urban areas and number of inhabitants</td><td>Rogaška Slatina: 4800
Šmarje pri Jelšah: 1600</td><td>Klanjec: 3230
Hum na Sutli: 1240</td></tr>
<tr><td>Population</td><td>38139</td><td>16700</td></tr>
<tr><td>Population density</td><td>85 inhabitant / km^2</td><td>120 inhabitants / km^2</td></tr>
<tr><td>Land use</td><td><table>
<tr><th></th><th>km^2</th><th>%</th></tr>
<tr><td>Agricultural land:</td><td>285.3</td><td>62</td></tr>
<tr><td>Forests</td><td>167.1</td><td>36.3</td></tr>
<tr><td>Inland wetlands</td><td>0.7</td><td>0.2</td></tr>
<tr><td>Urban, Industrial, commercial and transport units</td><td>4.6</td><td>1.0</td></tr>
<tr><td>Total</td><td>459.9</td><td>100</td></tr>
</table></td><td><table>
<tr><th></th><th>km^2</th><th>%</th></tr>
<tr><td>Agricultural land:</td><td>85.6</td><td>65</td></tr>
<tr><td>Forests</td><td>28.8</td><td>22.0</td></tr>
<tr><td>Inland wetlands</td><td>0.2</td><td>0.2</td></tr>
<tr><td>Urban, Industrial, commercial and transport units</td><td>2.8</td><td>2.1</td></tr>
<tr><td>Total</td><td>130.7</td><td>100</td></tr>
</table></td></tr>
<tr><td>Agriculture:</td><td><table>
<tr><th></th><th>km^2</th><th>%</th></tr>
<tr><td>Arable land</td><td>14.0</td><td>3.1</td></tr>
<tr><td>Heterogeneous agricultural areas</td><td>229.7</td><td>49.9</td></tr>
<tr><td>Pastures</td><td>39.6</td><td>8.6</td></tr>
<tr><td>Permanent crops</td><td>2.0</td><td>0.4</td></tr>
<tr><td>Scrub and/or herbaceous vegetation associations</td><td>2.2</td><td>0.5</td></tr>
<tr><td>Total</td><td>285.3 km^2</td><td>62% of total land</td></tr>
</table>rural population: 10% of the population; the main agricultural activity: livestock; farms are fragmented;</td><td><table>
<tr><th></th><th>km^2</th><th>%</th></tr>
<tr><td>Arable land</td><td>0.1</td><td>0.1</td></tr>
<tr><td>Heterogeneous agricultural areas</td><td>59.2</td><td>45.3</td></tr>
<tr><td>Pastures</td><td>26.3</td><td>20.1</td></tr>
<tr><td>Permanent crops</td><td></td><td>0.0</td></tr>
<tr><td>Scrub and/or herbaceous vegetation associations</td><td>13.4</td><td>10.2</td></tr>
<tr><td>Total</td><td>85.6 km^2</td><td>65% of total land</td></tr>
</table>rural population: 30% of the population; the main agricultural activity: vineyards, livestock; farms are fragmented;</td></tr>
<tr><td>Industry/Entrepreneurship and Tourism/Recreation</td><td>Glass manufacturing; sparkling water - drink production; 250 small enterprises (commerce, consulting, banking, construction services)</td><td>Industrial facilities in Hum na Sutli, crafts and manufacturing in Klanjec, Livestock farming and slaughterhouses in Gornji Čemehovec</td></tr>
<tr><td>Tourism/Recreation/Parks</td><td>Health Center Rogaška Slatina; Spa Center Olimje; Regional park Kozjansko; Landscape parks Boč and Jovsi;</td><td>Ethno village Kumrovec</td></tr>
</table>

Due to highly dispersed settlements with rural character there are only few sewer systems installed in these areas. Waste water is collected and treated in larger urban areas and settlements. Waste water treatment plants (WWTP) in Slovenia (in DPSIR framework defined as point source of pollution) are built in Rogaška Slatina (9000 Population Equivalent (in further text: PE)), Šmarje pri Jelšah (3200 PE), Podčetrtek (1990 PE): Small waste water treatment plants are in Kozje (1000 PE), Olimje (750 PE), Podsreda (250 PE), Kostrivnica (198 PE) and Sveti Florijan (150 PE) [10]. Waste water in other settlements is collected in individual permeable septic tanks if not emitted directly into small creeks and rivers. Figure 2 shows waste water treatment locations in Slovenia and agglomerations with more than 50 PE and with or without sewerage systems. In Croatia the WWTPs are in Kumrovec and Hum na Sutli [7], [21], [22], [24], [25].

5.2 Indicators of the state and impact

On the river Sutla there are seven monitoring locations of water quality, four in Croatia and three in Slovenia: Lupinjak (Croatia), Rogaška Slatina (Slovenia), Prišlin (Croatia), Zelenjak (Croatia), Rigonce (Slovenia), Rakovec (Slovenia), Harmica (Croatia). Water levels and discharges are monitored on six locations: Hum na Sutli (Croatia), Rogatec (Slovenia), Bratkovec (Croatia), Zelenjak (Croatia), Rakovec (Slovenia), Ključ (Croatia) [12], [26]. On the Sutla Lake there are data for discharges available only for one year (2009). Figure 3 shows monitoring locations of the state of water in the river Sutla. Data and information on water quality on locations on Slovenian side are obtained from Slovenian Agency for Environment, whereas on Croatian locations data and information are collected from Hrvatske vode.

Water status is categorized using two quality classification, one for the ecological status (five classes: high, good, moderate, poor, bad) and one for the chemical status (two classes: good, bad). Water quality trends as presented by quality classes (from first to fifth) for three clusters of parameters, oxygen regime, nutrients and biological indicators are presented in Figure 4. One can observe that due to nutrients water downstream from Prišlin before 2012 has been mainly classified not better than third class. The exception is Lupinjak, where nutrients have not caused any significant problems. Due oxygen in water at Zelenjak and Harmica water quality was in second or third class, but at Prišlin it is in third class from 2004 on. It has been even in fifth class from 2000 to 2002. By biological indicators, water along the Sutla river is more or less steady, having second class classification.

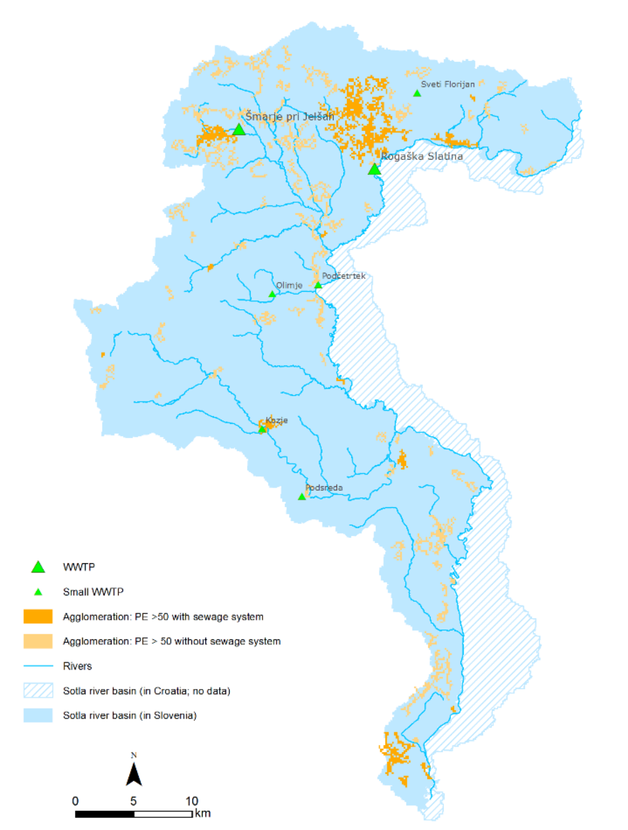


Figure 2: Waste water treatment locations in Slovenia and agglomerations with more than 50 PE and with or without sewerage systems.

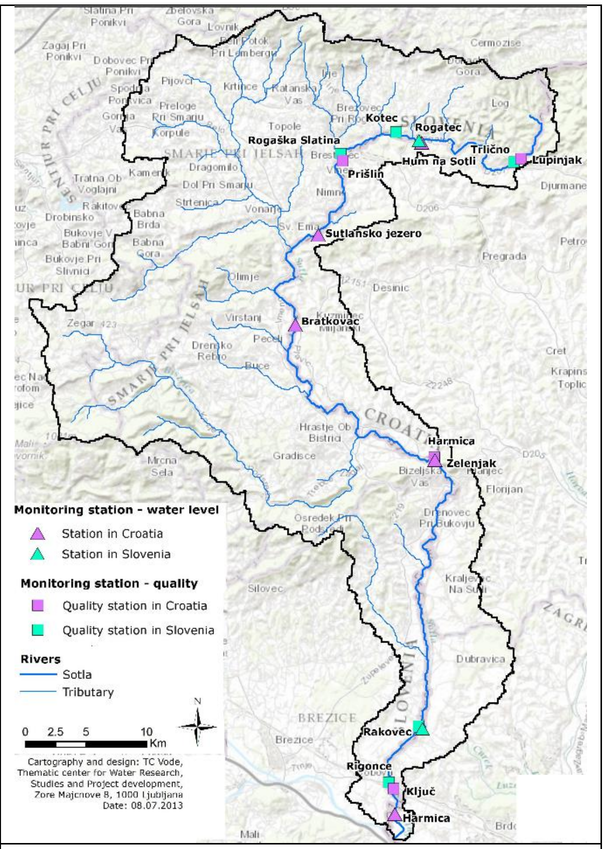
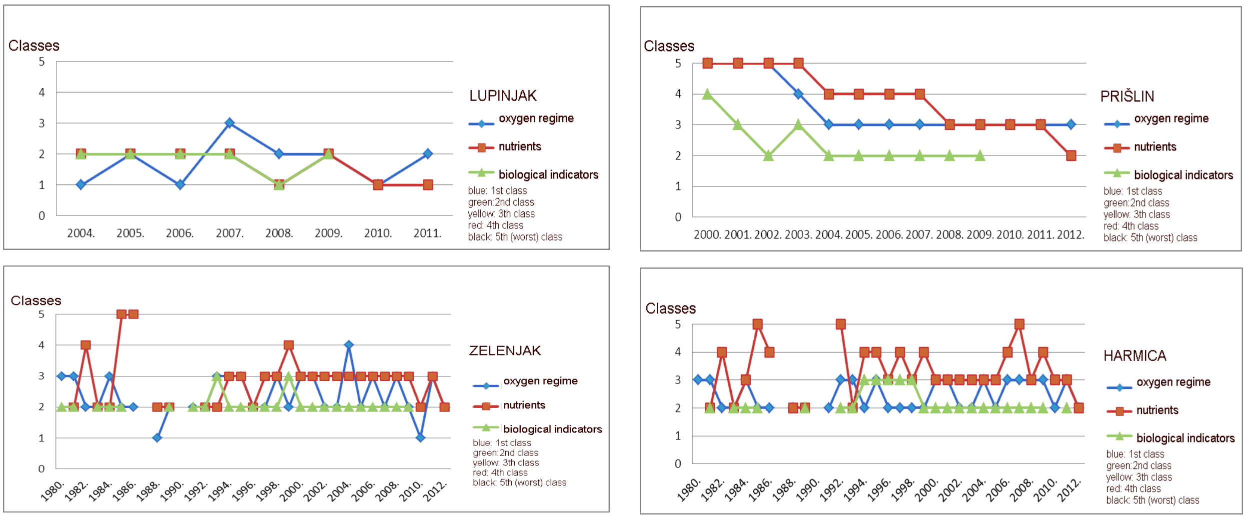


Figure 3: Monitoring stations of water level and monitoring station of water quality

The deviation of oxygen regime of monitoring stations Zelenjak in 2005 and Prišlin in 2007 is associated with the water temperature, which has a major impact on dissolved oxygen and oxygen saturation. For example, in the summer when the air temperature recorded above 25 ° C, the amount of dissolved oxygen are minimal, while in winter when the water is much colder, and the air temperature recorded about 5°C, dissolved oxygen concentrations are high. By evidence, the recorded high concentrations of COD (in those years), amounted to more than 25 mg O_2/l, while the minimum monthly flows was less than 1m^3/s. Also, large concentrations of BOD_5, occurred in 2001 in Harmica (24 mg O_2/l) while the flow was 1.15 m^3/s,



Monitoring station	chem. and phys. elements 2010	chem. and phys. elements 2011	biol. elements. makrozoobentos 2011	chem. and phys. elements 2012	biol. elements makrozoobentos 2012
Harmica	good	good	good	good	good
Zelenjak	good	good		good	good
Prišlin	poor	bad		bad	moderate
Lupinjak	good	good			

Fig. 4: Trends of water quality classes for four monitoring stations in Croatia

The first analysis of the authors showed that there is still a significant input of nutrients present in the Sutla river. The reasons are untreated urban waste water, surplus of nitrogen applied on agricultural land (to be modelled in future) and unfavourable oxygen conditions due to high temperatures and low water flows (water quantity problem). Eutrophication risks and risk of the presence of the faecal bacteria in the water are high. Agricultural activities may also lead to increased concentrations of suspended solids, pesticides, herbicides and salt in water.

In the further analysis we will model interdependence of dissolved oxygen and water temperature and interdependence of BOD_5 and COD with minimum monthly flows. Knowing both interdependences should direct management decisions to prevent eutrophication.

5.3 Responses

The programme for waste water treatment following Urban Waste Water Treatment Directive (UWWTD) [2] has been implemented in Slovenia since 2004 and in Croatia since 2012. Furthermore, the Cohesion, Structural and Environmental - Agricultural Funds from European Union have been lately used in Slovenia to reduce impact of the waste water pollution and pollution due agricultural activities to water resources. In Croatia there are also plans to build WWTPs in Kumrovec (instead of the existing one) and Klanjec.

5.4 Development of mathematical model for water quality

All of the stated facts indicate an urgent need for improving the water quality of the river Sutla and to redefine nature retention, the Sutla Lake, in the view of its multipurpose uses [1], [27].

An expert basis for political decisions shall be established. In the future activities are planned to prepare:

- analyse of reasons for bad water quality in the time of reservoir establishment will be made by application of a mathematical model and
- methodology of suitable water quality management along the Sutla river will be analysed using data and information collected through the DPSIR approach,

- proposal for efficient and optimal water quality management of the Sutla Lake will be prepared according to the stakeholder analysis and life-cycle assessment (LCA) concept.

On the base of DPIR approach, the research of the Sutla river basin will be evaluated from static reporting framework to dynamic modelling environment, from environmental to multi-disciplinary approach.

5.5. Some Proposals for the River Sutla Restoration

Research of the Sutla river basin has to be developed relating to the fact that the whole river Sutla is under the NATURA 2000 protection [4], [20], [27], [28] and *Guiding Principles for River Restoration* [29], including the importance of the nature retention:

- Dynamic characteristics of rivers - work with the river, not against it;
- Adapting human needs to natural river systems;
- Definition of reference conditions;
- Hydrologic connectivity;
- Public involvement, social processes and interactions important with increased scale;
- Adequate (long-term) multi-level monitoring;
- Multi-criteria analysis, cost-benefit analysis and economic evaluation.

River restoration has to be prepared in term of revitalisation role of nature retention and water quality management. Moreover, it has to be done in relation to water needs and well-being of inhabitants in the river Sutla catchment area.

6 CONCLUSIONS

Summarizing our analysis conducted for the Sutla river basin, a generalized DPSIR model has been prepared with particular focus on water quality and eutrophication. Agriculture (livestock), urbanisation (waste water) and flow alterations are among serious driving forces exerting pressures on the aquatic system altering also its biodiversity. Thus, river restoration in terms of revitalisation role of nature retention in water quality management, and the implementation of site-specific ecological requirements is urgently needed, specially related to nature protection areas and recreation resorts.

The common practice in the past of overexploitation of river water for various - usually competent- uses should be limited especially under the light of climate change and extremely dry and wet periods. The increased need for development should be coincided with environmental policy avoiding overexploitation of natural resources including protection of aquatic resources.

The river Sutla is a national border between Croatia and Slovenia, but nevertheless the important bridge linking inhabitants on both side of the river that have been living together for centuries. The prerequisite for successful water management of this border river is better co-operation between Croatia and Slovenia. The importance of controlling pollution sources confirmed the negative experiences from 1988, when Sutla Lake (water in accumulation) was heavily eutrophicated and therefore emptied. The downstream quality has deteriorated for years because of this release. The increasing hydrological extremes point to greater need for the integrated river basin management that include construction of retention on the upper part of the river basin (Slovenian) to protect downstream parts of the river basin (Croatian and Slovenian).

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