DOI: 10.17707/AgricultForest.62.2.01

Vojislav DJEKOVIC, Aleksandar ANDJELKOVIC,
Velibor SPALEVIC, Marko UROSEVIC, Sara LUKIC [1]

SIGNIFICANCE OF SURFACE WATER QUALITY FOR BASIN ECOLOGY

SUMMARY

The Council of the European Union and the European Parliament announced the objectives of the "sustainable policy in the water area" in 1996. Following those objectives and recommendations, control of surface water quality from the aspect of sustainable development of the region has been actively executed in Serbia. Water quality monitoring is primarily applied on large water basins, with a focus on small ones as well, especially due to the fact that small basins have a significant role in environmental protection and water supply. This paper presents the significance of regular water control of the River Ralja in Central Serbia. Monitoring was executed in different seasons, and this paper presents results for the period 2011-2012. The aim of this paper is to present the situation of the water basin and point to the significance of surface courses for water supply of the population. Another objective is to point to issues emerging in the phase of using and disposing of used waters, as well as the option of using the River Ralja water for irrigating arable land, in the aim of obtaining healthy and high-quality agricultural produce.

Keywords: monitoring, water quality, living environment, wastewaters.

INTRODUCTION

The battle for water is as old as the life on the Earth. A man certainly first fought for water, and then against floods. That battle for water actually continues today, with a conclusion that it has never stopped. Today's battle is more complex and difficult and will be even harder for future generations. Once sufficient supplies of water for human use could be found in nature, but the situation is different today. There is virtually no water left suitable for use that has not been upgraded by a human action, thus water has become a commodity, a commodity of special significance. It is no longer a raw material only; it is now a subject of work, a tool for work. Not only is it used for physiological needs, but for nearly all technological procedures. Furthermore, it is important to note that

[1] Vojislav Djekovic, Aleksandar Andjelkovic, Faculty of Forestry, University of Belgrade, SERBIA; Velibor Spalevic, Department of Geography, University of Montenegro, MONTENEGRO; Marko Urosevic, The Institute Jaroslav Cerni, Belgrade, SERBIA, Sara Lukic, Faculty of Forestry, University of Belgrade, SERBIA.

Paper presented at the 6th International Scientific Agricultural Symposium "AGROSYM 2015"

Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

water has been, is and will always be an irreplaceable food item. (Mihailovic, 2007).

The quality of surface water plays a significant role in developing urban and suburban settlements. In the spatial layout of the territory of Serbia, urban settlements always develop near surface watercourses and accumulations. Water provides many benefits: it ensures drinking water, water for irrigating arable land, food for survival, and a comfortable environment for sports and recreation. This paper presents the data on the water quality of surface watercourses for the basin of the River Ralja, which belongs to the basin of the River Velika Morava, namely the River Danube.

The spring of the streams that create the River Ralja is located at Parcani Rising and Mt. Kosmaj, at the 426 m elevation point, by combining several tributaries. The quality of the spring tributaries waters are ranked as the first Class, but as rural and suburban settlements do not have regulated utility infrastructure, occasional pollution incidents occur along the watercourse and in the spring area of the basin. Wastewaters from these settlements are disposed of in cesspits, which are in most cases drainable and overflowing, and wastewaters from them and cattle farms run off to ditches and streams. As a result, even some streams in the spring area of the basin are polluted with wastewaters. (Milosevic, *et al*., 2014).

Another source of pollution is illegal solid waste landfills, as waste is washed away with rain and poisonous and hazardous substances get to surface courses and ground aquifer waters. (Andjelkovic, *et al*., 2013).

The third source of pollution is pesticides and artificial fertilisers, used in agricultural and fruit production. Individual farmers are often not trained in using these substances properly and sometimes they exceed recommended amounts. In addition, used packaging of these substances is disposed of at non-regulated and unsafe locations (illegal landfills). After using chemical substances, they are washed away with rain and snow to ground and surface watercourses. Packaging of used substances is not recyclable, thus it gets piled up for years, contaminating specific locations, which then become local sources of pollution of the living environment and watercourses. (Djekovic, V., 2004)

The hydrographic network of the River Ralja basin starts in the spring area at the hills of Mt. Kosmaj and Parcani Rising, while from the settlements of Parcani and Ralja, the river runs near Sopot, Mladenovac, in the direction of the settlement of Mali Pozarevac. After that, the watercourse of the River Ralja is regulated in Belgrade-Nis motorway section (Figure 3).

In the central and lower section, the River Ralja runs through the plain agricultural area, settlements: Umcari, Kolari, and Smederevska Ralja. These settlements have no regulated sewage infrastructure and wastewater treatment systems. The River Ralja has no major tributaries in the central section, but has several minor ones and direct runoffs of communal wastewaters. (Andjelkovic, *et al*., 2014).

At around 10 km from the spring, near the settlement of Umcari, the Public Health Institute of Belgrade controls water quality on a quarterly basis. The River Ralja is of exceptional significance for supplying the population in this region with high-quality drinking water and high-quality water for irrigating agricultural and other crops. The relevance of the quality of water for irrigation is evident, as large part of Belgrade is supplied with agricultural produce from this region at green markets, and the quality of water for irrigation generally affects the quality of food and health of the population (Dragovic et. al. 2012).

Very often specific physical-chemical and bacteriological parameters of surface water significantly exceed the maximum permitted concentrations (MPC) for the Class 3 of water quality. It is also found that water samples are occasionally bacteriologically and chemically unsafe. This phenomenon is regularly registered in summer periods, when due to a drought water flow is low, while water demand is high. In these periods, the oxygen regime of the River Ralja water is also disturbed (Table 1).

In the lower section of the River Ralja, landfills of the ironworks in Smederevo represent a special threat for the living environment and ground and surface waters. (Letic, *et al*. 2012)

The Public Health Institute of Pozarevac has been conducting physical and chemical analyses of the River Ralja water 12 times a year (once a month), for an extended period of time (20 years). Constant contamination of surface water causes the pollution of ground (well) waters. Furthermore, the ironworks in Smederevo releases its wastewaters to the River Ralja profile. The concentration of suspended substances is higher than permitted (MPC) for the Class 3 of quality. (Salama *et al*., 2013) The effluent contains a high rate of the following: iron, zinc, ammonia, high five-day chemical oxygen consumption (COC5), as well as phenols, phosphorus, nitrates and nitrites. (Djekovic, V., 2007).

The significance of the River Ralja basin is confirmed by the fact that it is the only watercourse in this part of Central Serbia that connects four municipalities. The River Ralja waters may be a valuable water resource for water supplies for the population, survival of florae and faunae. Therefore, it has been necessary to evaluate the quality of surface waters and define the impact of the waters polluted in such a manner on the environmental potential of the basin. (Drsgovic, S,. et. al.2012)

The aim of the project has been to register polluters, point to pollutions before the ironworks in Smederevo landfills and strive to apply legal and other measures to prevent degradation of such an important area in the vicinity of the capital. As control of environmental pollution is not possible in all periods of a day, during a 24-hour period, it is necessary to define guidelines for efficient protection of the living environment, surface waters and ground waters. In that respect, it is vital to educate the population efficiently and raise public awareness regarding the significance of a healthy living environment and pollution hazards. To conduct this program, education needs to start with the youngest members of the population, including public media as a channel.

Hydrography of the River Ralja Basin

More than a half of the River Ralja watercourse (cca 25km) lies in the direction of Belgrade – Nis motorway, thus the Ralja basin is located between the River Danube basin to the north and the Veliki Lug and Jasenica basins to the south. The terrain of the River Ralja basin is a consequence of forest devastation and activation of erosion processes caused by the movement of material and its occasional retention in the hydrographic network of the watercourse. (Krstic, M., et. al., 2013)

Morphological processes in the river basin and bed have resulted in the erosion and movement of easily degradable material and its transportation along the river. In the zones with a higher drop of the river bed, the bed deepens, the banks are undermined and eroded and high volumes of deposits, transported through the hydrographic network of the basin by the water flow in flooding phases, are created. Moving deposits are comminuted along the watercourse and move mainly as suspended deposits in the central and lower watercourse. (Djekovic *et al.*, 2013). A suspended deposit is a natural coagulant and a transporter of a pollution wave along the river. Its rate decreases in a dry period of a hydrological year, and increases with precipitation and higher flows. A rate of diluting the pollution concentration plays an important role in using the River Ralja water for irrigation and water supply. Another issue is emulsified substances emerging in the river bed and not depending particularly on the water flow rate. (Letic *et al*., 2008).

The River Ralja flow rate is characterised by the succession of constant and occasional flows. In a period of heavy rain and storms, the level of specific tributaries and streams rises, they run off their bed and flood the bank zone. There is no practice of monitoring the water level of the River Ralja, but according to previous surveys and traces, it has been concluded that the average annual flow is $Q = 1{,}55m^3 \cdot s^{-1}$ and the water depth in the profile for this flow rate in the upper and central sections of the basin ranges between 20cm to 30cm. In the previous period, the River Ralja has been used as a receptor of wastewaters from production facilities of various types of industry, primarily foundries and ferrous metallurgy, food industry, agriculture, urban settlements and individual farms. Many production facilities are not operating at the moment, due to the economic crisis, so the quality of water along the basin has improved in a natural manner. (Djekovic, *et al*., 2010).

MATERIAL AND METHODS

This paper is based on the results of a survey on the quality of the living environment of the River Ralja basin in Central Serbia, conducted by the Public Health Institute of Serbia, Public Health Institute of Pozarevac, and some surveys of the paper authors. The total length of the River Ralja is 51km, and the basin area covers 310km2. The River Ralja runs through 4 municipal areas (Sopot, Mladenovac, Grocka and Smederevo). After merging with the River Jezava at the territory of the municipality of Smederevo, it enters the River Velika Morava, around 5km away before its confluence with the River Danube (Figure 1).

The survey methods presented in this paper are based on field surveys, sampling of water from various profiles of the river course. These activities have established change in the water quality, including the presence of foul smell, as an indicator of environmental pollution. As water supply of all the settlements in the River Ralja basin is so far based on well ground water, and surface water of the River Ralja is used for irrigating agricultural land and accumulation of used up aquifer waters, as well as for the preservation of the ecology of the watercourse and the basin, the quality of surface and ground waters is of exceptional importance. In order to successfully preserve the living environment of the basin, it is necessary to maintain the quality of surface waters.

Figure 1. Position of the River Ralja basin (Izvor: origin)

The significance of agricultural land near large urban centres (Belgrade - Smederevo) has a huge impact on the production and supply of these cities with healthy food. The following methodology was used for surveying the impact of specific parameters of pollution on the quality of the River Ralja water and the quality of ground waters in the basin:

- -Experimental survey on the watercourse and in the basin of the River Ralja, with the direction of survey divided in two groups:
- -direct definition of quality parameters on selected profiles of the watercourse, from the spring to the confluence;
- -registration of point sources of pollution along the river;
- -Sampling of water and sediments for physical-chemical and bacteriological analyses.

For further analysis, the entry data consist of results of the direct measurement and, based on the measurement results, the assessment of the impact of local pollutions on the water quality of the River Ralja basin was executed.

The method of direct measurement of change in the water quality was applied, due to releasing communal wastewaters in the river, as well as a volume and concentration of specific polluting elements in the watercourse. Registration of illegal landfills with industrial and communal waste on the field has resulted in the conclusion that waste and hazardous substances enter the River Ralja surface waters from these locations with precipitation.

This paper presents part of the results of measurements and surveys of the quality of water and sediments conducted in the course of 2011 and 2012. Due to a huge volume of the measurements and analyses, specific data have been selected to present physical-chemical and bacteriological surveys.
the gathered data are presented in the tables in this paper.

RESULTS AND DISCUSSION

Wastewaters in the River Ralja basin

<u>*Wastewaters from settlements*</u>

The River Ralja basin includes 21 settlements with the population of around 35,000. The residents are mainly engaged in agriculture, fruit and wine growing and cattle breeding. The settlements do not have a system of channelling and draining wastewaters. Instead, wastewaters are disposed of in cesspits, which are mainly drainable and overflowing, or are occasionally emptied, with the effluent content disposed of in the River Ralja or some of its tributaries.

Based on the field surveys, it is concluded that the wastewater volume from these settlements ranges at around 70g ER/day, (ER – equivalent resident), suspended substances (SUS) 65g ER/day, 5-day biochemical oxygen consumption (BOC5) 9g ER/day, nitrogen (N) 0.6g ER/day, phosphorus (P) 0.5g ER/day. (Andjelkovic *et al*., 2013)

The measurements have found that out of the overall volume of used water, around 70% is disposed of in cesspits, which means that around 4,900 m3/day of wastewater come from households in the River Ralja basin, including around 1.715 tons of suspended particles, 1.6 tons of organic waste, 220.5kg of nitrogen and 14.7kg of phosphorus. After filling up cesspits, their content is released to the river bed, as there is no control related to this issue. (Andjelkovic *et al*., 2013)

Accordingly, around 4,900 m3 of water per day is used in the River Ralja basin. That volume of water runs off to surface courses and infiltrates the ground. Used wastewaters are highly polluted with organic matter, nitrates, nitrites and ammonia. In addition, around 2.3 tons of organic matter, 0.64 tons of nitrogen, high volumes of phosphorus, potassium, iron, chlorides, etc., are added to the hydrographic network of the basin on a daily basis. Furthermore, a range of metals in traces is registered, affecting the water and soil quality. (Djekovic *et al*., 2008). The valley of the River Ralja, downstream from mali pozarevac, is located in a close proximity of belgrade - nis motorway and belgrade - mala krsna railway. The river bed is regulated upon the system of land regulation, with occasional protection and stabilisation of bevels and the river bed. (Figure 3).

There are no dykes along the river. Instead, the grade level is brought down, so the regulation is at the same time a system of surface drainage, in case of value and surface sloughing, while the right side of the river valley is protected with the motorway dyke.

Figure 2. Landfills of waste, sediment mud to the River Ralja bed (Photo: V. Djekovic, 2013)

Figure 3. Regulation of the River Ralja with the local enforcement of flow profile (Photo: V. Djekovic, 2012)

<u>Influence of communal wastewaters and small business wastewaters on the quality of surface watercourse</u>

As the river follows the direction of Belgrade – Nis motorway, 11 petrol stations have been built, as well as many car repair shops, car washes, Horeca facilities and motels. It was very difficult in this survey to establish a volume and pollution rate of wastewaters from these facilities that enter the profile of the River Ralja. Central activities in these facilities are executed in late afternoon and night hours. Based on a total number of workforces in these facilities, a volume of sanitary and faecal wastewaters that enters the River Ralja tributaries has been determined. The workforce at petrol stations is around 150, in craft shops 100 and in Horeca facilities 90, or 340 in total. With 50 litres of estimated water consumption per user a day, around $17 m^3 \cdot day^{-1}$ of sanitary and faecal wastewaters enter the River Ralja streams and course without any treatment. By washing off spilt petroleum and its derivatives from the working areas of petrol stations, a significant volume of water with a high rate of grease, petroleum and heavy metals enters the river. Chemical oxygen consumption is elevated due to a high rate of chemical compounds in water, while biochemical consumption is very low, resulting in a very small rate of biologically active organisms in water. Most petrol stations have deployed grease and petroleum separators before releasing water to streams, but many of the separators are out of function. A high volume of water, with a high concentration of detergents and suspended matter, from car washes, horeca facilities and motels runs off to the streams. It is difficult the determine the exact volume of these waters, but it is estimated at around 30m3·day-1. Results of the quality water monitoring are presented in the Tables 1, 2 and 6.

Table 1. Monitoring of the River Ralja water quality in the course of 2012 (Source: Original)

Date	t^0C	pH	O_2	$\%O_2$	BOC_5	$KMnO_4$	COC	Susp. part.	Total phosph.
09/04/2012	13.5	8.1	8	76	0.7	23.7	5.9	3	0.128
23/07/2012	19.5	8	3.9	42	1.4	30.7	7.7	39	0.196
20/9/2012	11.3	7.9	4.9	48	3.6	22.2	4.3	25	0.205
12/12/2012	5.3	8.1	6.2	55	1.8	18.2	5.0	9	0.175

Table 2. Results of monitoring of the River Ralja water quality in the course of 2012 (source: original)

Date	Ortho phosph.	Dry residue	Electro conduct.	Alkalinity	Hardness	Fe	NH_3	NO_2	NO_3	TOC
09/04/2012	0.176	920	1230	493.5	517	0.05	0.23	0.017	0.7	6.63
23/07/2012	0.176	920	1230	493.5	517	-	0.34	0.021	1.29	8.54
20/09/2012	0.305	889	1055	392.4	490	0.004	0.45	0.042	0.98	7.97
12/12/2012	0.168	853	1120	385.0	510	0.008	0.29	0.009	0.75	6.28

Table 1 shows that the concentration of oxygen in water is high and that it decreases with an increase of temperature, while chemical oxygen consumption rises, reaching a peak in summer months, when a rate of chemical substances in water is higher (grease, oil, petroleum and its derivatives, detergents). Over time, biochemical oxygen consumption in the lower section of the river decreases, as the content of organic matter in water is reduced, resulting in lower-rate activity of microorganisms and their metabolism.

Table 2 shows that in the course of 2012 all the quality parameters were above the maximum permitted rate for waters of the class ii and iii. Rates of iron, nitrates and nitrites, as well as electrolytic conductivity, rise in the summer months. Dry residue is also increased, indicating to an extent to the presence of mineral particles in water (suspended erosion deposit).

The survey and quality control of recent waters has established a high rate of suspended particles, fluctuating in the course of the year and reaching a peak in the autumn months (October, November and December). The rate of organic matter was below the mpc for the class ii of quality in august and September. It is interesting to note that higher turbidity, caused by the presence of suspended particles, did not result in higher biochemical and chemical oxygen consumption. On the other hand, after heating at 1050c, dry residue is nearly always above 500mg/l, indicating to the origin of suspended particles or (water turbidity) mineral content. The oxygen rate is regularly below the permitted limit for the water of class ii, and the rate of oxygen saturation decreases with a drop of temperature of water and air. Another issue regarding the pollution of surface and recent waters in the lower section of the River Ralja basin is the presence of nitrates and nitrites, pointing to a conclusion that the pollutions are of faecal origin. The presence of heavy metals in water (zinc, iron and lead) points to industrial pollutions, while phenols point to the pollutions which might be of organic origin. Namely, decomposition of organic matter with the reduced presence of oxygen creates hazardous phenol compounds which, even at the upper limit of the mpc, point to the fact that these waters are toxic and are not to be used for water supply. The quality control on 06/11/2011 showed that the sample had a high rate of suspended particles, with metal analyses conducted from a decanted part of the sample. Only total iron was measured in the homogenised sample without decanting, with the result of 4.94 mg/l, which is not presented in the table. At the repeated control in October, on 09/10/2011, it was established that the composite sample had a higher rate of suspended matter, with metal analyses conducted from a decanted part of the sample. Only total iron was measured in the homogenised sample without decanting, with the result of 0.95 mg/l.

In November, on 20/11/2011, an increased rate of suspended matter was registered, and the control of heavy metal content on the homogenised sample without decanting showed the elevated rate of iron of 2.11 mg/l. In December, on 06/12/2011, the rate of iron was not reduced significantly. The sample had a high rate of suspended matter, with metal analyses conducted from a decanted part of the sample. Only total iron was measured in the homogenised sample without decanting (fe= 2.00 mg/l).

Table 3. Results of testing physical and chemical parameters of recent waters in the course of 2011 (Source: Original)

Testing report				Testing date					
Parameters	Me. unit	MPC	13/8	11/9	9/10	6/11	20/11	6/12	Standard
pH		6.8-8.5	7.9	8.1	7.6	8.2	7.5	7.4	ISO 10523:194
Oxygen O_2	mg^1l^{-1}	>6.0	2	6.5	4.2	6.6	1.3	1.5	SRPS ISO 5814:1994
O_2 Oxy. saturation	%		23	77	50	78	14	17	SRPS ISO 5814:1994
BOC_5	mg^1l^{-1}		7.2	2.5	4.9	2.4	1.1	4.8	SRPS ISO 5814:1994
Consumption $(KmnO_4)O_2$	mg^1l^{-1}		19.5	18.2	21	15.5	25	22	PRI1 P-IV-9a
COC from КМнО$_4$	mg^1l^{-1}	12	4.9	3.0	5.2	3.0	37	34	SRPS ISO6060:1990
Suspend. matter	mg^1l^{-1}	30.0	6	4	225	600	25	11	SMEWW19th m 2540
Dry residue 105^0C	mg^1l^{-1}		650	386	575	379	526	535	SMEWW19th m 2540
Electrolyt. conduct.	µS/cm		930	530	770	550	610	610	ISO7888:1985
NH_4	mg^1l^{-1}		0,09	1.38	0.13	1.43	3.33	3.06	ISO 14911:1998
Nitrites NO_2/N	mg^1l^{-1}	10.0	0.053	0.112	0.036	0.105	0.02	0.02	PPI 1 P-V-32/A
Nitrates NO/N	mg^1l^{-1}	0.05	2.60	1.800	5.80	1.30	1.60	1.70	SMEWW 19th m 4500NO3B
Phenols	mg^1l^{-1}	0.001	<0.001	0.002	0.001	0.003	<0.001	<0.001	SRPS ISO 6439:1997
Arsenic As	mg^1l^{-1}		0.003	0.002	<0.001	0.002	0.008	0.008	EPA 206.3
Iron Fe	mg^1l^{-1}	0.30	0.097	0.590	0.126	0.048	0.293	0.251	EPA200.7 Rev 5
Zink Zn	mg^1l^{-1}		0.002	0.09	0.004	0.183	0.008	0.007	EPA 200.7Rev 5
Lead Pb	mg^1l^{-1}		<0.005	<0.010	<0.010	<0.01	<0.005	<0.005	EPA 2007Rev 5

Based on other parameters, it is concluded that the River Ralja waters are constantly polluted, regardless of a season. The quality of surface water changes abruptly after the entry point of the ironworks in Smederevo collector to the River Ralja. Sudden changes of the pH value confirm that the pollutions are constant, with water turbidity SiO2 increasing abruptly as well (mg1·l-1).

Biochemical oxygen consumption is also related to these changes, pointing to the presence of organic pollution of the river. Before the entry point of wastewaters from the ironworks in Smederevo, the rate of iron in the sample ranged from 1.08 $mg^{1}\cdot l^{-1}$ to 15.78$mg^{1}\cdot l^{-1}$, to increase to 3.07 $mg^{1}\cdot l^{-1}$ to 52.24 $mg^{1}\cdot l^{-1}$after the entry point. All testing methods were standardised and in accordance with the standard-defined regular procedure (Tables 3, 4).

Table 4. Results of physical and chemical testing of water in the course of 2012 (Source: Original)

Organoleptic testing:		Visual water colour: (clear, pale yellow, purple)							
No.	Parameter	Meas. unit	MPC	Received value					Method type
				13/04/1	25/05/1	24/06/1	06/07/1	11/08/1	
1	Air temp.	-	-	21.1	28.4	31.4	30.0	32.2	-
2	Water temp.	°C	-	20.8	21.7	21.3	21.4	22.3	1.1.1-S
3	Turbidity	mg^1l^-	-	<10	20	30	800	78	P[1)]-M-P-IV-
4	pH value	-	6.8-8.5	8.0	8.05	8.10	8.05	8.12	P[1)]-M-P-IV-
5	Nitrates (as N)	mg^1l^{-1}	10.0	0.47	0.266	0.522	1.090	1.95	P[1)]-M-P-V-
6	Nitrites (as N)	mg^1l^{-1}	0.05	<0.002	0.012	0.003	0.006	0.008	P[1)]-M-P-V-
7	Ammonia ion (as	mg^1l^{-1}	1.00	0.097	0.233	0.583	0.389	0.455	P[1)]M-P-V-2-
8	Chlorides	mg^1l^{-1}	-	79.08	98.14	83.48	53.05	54.25	SRPS SO
9	Consumption	mg^1l^{-1}	-	19.28	19.76	33.19	43.36	45.26	P[1)]-M-P-IV-
10	Iron (Fe)	mg^1l^{-1}	0.30	0.25	0.25	0.83	1.0	1.26	P[1)]-M-P-V-
11	Detergents - anionic	mg^1l^{-1}	-	0.030	<0.030	0.127	0.278	0.285	1.1.28-S
12	Phosphates	mg^1l^{-1}	-	<0.030	0.708	0.795	0.831	0.753	APHA[8)]-
13	Phenols	mg^1l^{-1}	0.001	<0.001	0.001	<0.001	<0.001	0.002	SRPS IS0 6439:1997-
14	Oxygen (O_2)	mg^1l^{-1}	>6.0	6.73	4.79	4.65	6.82	4.85	P[1)]-M-P-IV-12/B
15	COC	mg^1l^{-1}	12	12	17	11	17	17	P[1)]-M-P-IV-10
16	BOC_5	mg^1l^{-1}	4	10.58	9.16	6.34	17.48	16.95	SRPS ISO 5815:1994
17	Residue from unfiltered water	mg^1l^{-1}	-	692.0	650.0	776.0	520.0	695	P[1)]-M-P-IV-7
18	Residue from filtered water	mg^1l^{-1}	1000	652.0	636.0	754.0	490.0	746	VM 11
19	Suspended particles	mg^1l^{-1}	30.0	40.0	14.0	22.0	30.0	29	P[1)]-M-P-IV-9
20	Sediment matter	ml/l/2h	-	<0.10	0.10	0.10	0.10	0.11	P[1)]-M-P-IV-8

Based on the presented surveys, the total volume of wastewaters from small business facilities is around 50$m^3\cdot day^{-1}$. Wastewater that runs off to the surface river profile is exceptionally polluted and has a negative effect on the quality of the River Ralja water and the living environment. Oxygen consumption (BOC_5) for sanitary (faecal) wastewater is estimated at (O_2) =200g^{1}. m^{-3}, and for the water from washing equipment and vehicles (O_2) =300g^{1} $m^{-3.}$

Below are results of physical and chemical testing of the River Ralja water quality at the measurement point 4 in Radinci, Table 7.

Table 5. Physical and chemical features of the River Ralja water upstream from the entry point of wastewaters from the ironworks in Smederevo (Source: Original)

Organoleptic testing:		Visual water colour: (clear, pale yellow, purple)							
No.	Parameter	Meas. unit	MPC	Received value					Method type
				13/04/1	25/05/1	24/06/1	06/07/1	11/08/1	
1	Air temp.	-	-	21.1	28.4	31.4	30.0	32.2	-
2	Water temp.	°C	-	20.8	21.7	21.3	21.4	22.3	1.1.1-S
3	Turbidity	mg^1l^-	-	<10	20	30	800	78	P1)-M-P-IV-
4	pH value	-	6.8-8.5	8.0	8.05	8.10	8.05	8.12	P1)-M-P-IV-
5	Nitrates (as N)	mg^1l^{-1}	10.0	0.47	0.266	0.522	1.090	1.95	P1)-M-P-V-
6	Nitrites (as N)	mg^1l^{-1}	0.05	<0.002	0.012	0.003	0.006	0.008	P1)-M-P-V-
7	Ammonia ion (as	mg^1l^{-1}	1.00	0.097	0.233	0.583	0.389	0.455	P1)M-P-V-2-
8	Chlorides	mg^1l^{-1}	-	79.08	98.14	83.48	53.05	54.25	SRPS SO
9	Consumption	mg^1l^{-1}	-	19.28	19.76	33.19	43.36	45.26	P1)-M-P-IV-
10	Iron (Fe)	mg^1l^{-1}	0.30	0.25	0.25	0.83	1.0	1.26	P1)-M-P-V-
11	Detergents - anionic	mg^1l^{-1}	-	0.030	<0.030	0.127	0.278	0.285	1.1.28-S
12	Phosphates	mg^1l^{-1}	-	<0.030	0.708	0.795	0.831	0.753	APHA8)-
13	Phenols	mg^1l^{-1}	0.001	<0.001	0.001	<0.001	<0.001	0.002	SRPS IS0 6439:1997-
14	Oxygen (O_2)	mg^1l^{-1}	>6.0	6.73	4.79	4.65	6.82	4.85	P1)-M-P-IV-12/B
15	COC	mg^1l^{-1}	12	12	17	11	17	17	P1)-M-P-IV-10
16	BOC_5	mg^1l^{-1}	4	10.58	9.16	6.34	17.48	16.95	SRPS ISO 5815:1994
17	Residue from unfiltered water	mg^1l^{-1}	-	692.0	650.0	776.0	520.0	695	P1)-M-P-IV-7
18	Residue from filtered water	mg^1l^{-1}	1000	652.0	636.0	754.0	490.0	746	VM 11
19	Suspended particles	mg^1l^{-1}	30.0	40.0	14.0	22.0	30.0	29	P1)-M-P-IV-9
20	Sediment matter	ml/l/2h	-	<0.10	0.10	0.10	0.10	0.11	P1)-M-P-IV-8

The conclusion is that the River Ralja waters before the ironworks in Smederevo, namely upstream from the entry point of wastewaters from the ironworks collector, are on the lower limit of the Class II and III of quality.

Concentration of suspended particles, iron, zinc, COC, BOC, phenols and ammonia is above the maximum permitted concentration (MPC). In the survey period, the sampling dynamics was twice a month. Maximum concentrations of suspended particles in the course of 2011 ranged from 160 $mg^{-1}\cdot l^{-1}$ to 498$mg^{-1}\cdot l^{-1}$, of ammonia from 0.09 $mg^{-1}\cdot l^{-1}$ to 3.33.667 $mg^{1}\cdot l^{-1}$, COC from 3 $mg^{1}\cdot l^{-1}$ to 37 $mg^{1}\cdot l^{-1}$, COC_5 from 1.1 $mg^{1}\cdot l^{-1}$ to 7.20 $mg^{1}\cdot m^{-3}$, iron from 0.048 $mg^{1}\cdot l^{-1}$ to 0.59 $mg^{1}\cdot l^{-1}$, zinc from 0.02 $mg^{1}\cdot l^{-1}$ to 0.183 $mg^{1}\cdot l^{-1}$, and phenols from 0.001 $mg^{1}\cdot l^{-1}$ to 0.003 $mg^{1}\cdot l^{-1}$. Increased levels of ammonia, suspended particles, COC and BOC are the consequence of the pollution caused by communal wastewaters from agricultural activities, unresolved issue of drainage and treatment of wastewaters from farms, and a lack of a sewage system.

Table 6. Physical and chemical features of the River Ralja water upstream from the entry point of wastewaters from the ironworks in Smederevo (Source: Original)

	Unit	19/01/2012	11/02/2012	13/03/2012	17/05/2012	14/06/2012	18/07/2012	20/08/2012
TurbiditySiO_2	mg^1l^{-1}	300	30	800	20	50	60	200
pH value	mg^1l^{-1}	8.15	8	8.65	8.15	8	7.8	8.05
Nitrates (as N)	mg^1l^{-1}	2.685	1.323	0.782	0.346	0.457	0.513	0.425
Nitrites (as N)	mg^1l^{-1}	0.009	0.003	<0.002	0.002	0.003	0.003	0.03
Ammonia ion	mg^1l^{-1}	0.078	0.097	0.583	0.194	0.233	0.194	0.971
Chlorides (Cl	mg^1l^{-1}	81.13	72.69	43.33	70.47	77.01	50.83	40.99
$KMnO_4$	mg^1l^{-1}	44.56	54.05	113.16	23.11	23.26	19.09	33.5
Iron (Fe)	mg^1l^{-1}	1	0.2	0.67	0.67	0.33	0.33	0.67
Detergents	mg^1l^{-1}	< 0.030	0.038	0.046	0.27	0.472	0.018	<0.03
Phenols	mg^1l^{-1}	0.006	0.003	0.002	<0.001	<0.001	<0.001	<0.001
Phosphates	mg^1l^{-1}	0.521	0.29	-	0.29	0.04	0.726	0.983
Residue from unfiltered	mg^1l^{-1}	582	652	834	606	626	638	602
Residue from filtered water	mg^1l^{-1}	522	638	434	588	608	528	566
Suspended	mg^1l^{-1}	60	14	400	18	18	110	66
Sediment	mg^1l^{-1}	< 0.10	<0.10	1	<0.10	0.1	0.1	0.3
Oxygen	mg^1l^{-1}	12	12.23	9.85	7.75	5.17	6.17	6.15
COC	mg^1l^{-1}	19	31	30	20	22	20	4
BOC_5	mg^1l^{-1}	10.52	3.07	52.4	7.98	4.69	5.36	22
Copper	mg^1l^{-1}	< 0.003	<0.003	0.016	<0.003	<0.03	<0.003	<0.03
Zinc	mg^1l^{-1}	0.101	0.056	0.027	0.031	0.079	0.058	0.043
Chrome total	mg^1l^{-1}	0.006	<0.006	<0.006	0.006	<0.006	<0.006	<0.006
Cadmium	mg^1l^{-1}	< 0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Lead	mg^1l^{-1}	< 0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 7. Results of physical and chemical testing of the River Ralja water in Radinci M – 4 (Source: ZJZ-Srbije)

Organoleptic testing		Unclear, pale yellow			
	Parameter	Meas. unit	MPC	Received value	Method type
1	Air temperature	°C	-	10.5	-
2	Water temperature	°C	-	20.0	1.1.1-S
3	Turbidity (SiO_2)	$mg^1 \cdot l^{-1}$	-	100	1.1.69-S
4	pH value	-	6.8-8.5	8.20	1.1.6-S
5	Nitrates (as N)	$mg^1 \cdot l^{-1}$	10.0	1.617	1.1.52-S
6	Nitrites (as N)	$mg^1 \cdot l^{-1}$	0.0.	0.122	1.1.53-S
7	Ammonia ion (as N)	$mg^1 \cdot l^{-1}$	1.0	1.554	1.1.18-S
8	Chlorides (Cl)	$mg^1 \cdot l^{-1}$	-	49.75	1.1.36-S
9	Consumption $KMnO_4$	$mg^1 \cdot l^{-1}$	-	12.20	1.1.10-S
10	Iron (Fe)	$mg^1 \cdot l^{-1}$	-0.30	1.0	1.1.32-S
11	Detergents anionic	$mg^1 \cdot l^{-1}$	-	0.556	1.1.28-S
12	Phenols	$mg^1 \cdot l^{-1}$	0.001	0.001	1.1.29-S
13	Phosphates	$mg^1 \cdot l^{-1}$	-	0.393	1.1.31-S
14	Residue from unfiltered water evaporation	$mg^1 \cdot l^{-1}$	-	342.0	1.1.7-S
15	Residue from filtered water evaporation	$mg^1 \cdot l^{-1}$	1.000	308.0	1.1.7-S
16	Suspended particles	$mg^1 \cdot l^{-1}$	30.0	34.0	1.1.9-S
17	Sediment matter	$mg^1 \cdot l^{-1} \cdot 2h$	-	0.10	1.1.8-S
18	Oxygen	$mg^1 \cdot l^{-1}$	> 6.0	7.40	1.1.14-S
19	COC	$mg^1 \cdot l^{-1}$	12	26	1.1.11-S
20	BOC_5	$mg^1 \cdot l^{-1}$	4	6.28	1.1.15-S
21	Copper	$mg^1 \cdot l^{-1}$	0.10	0.03	1.1.23-S
22	Zinc	$mg^1 \cdot l^{-1}$	0.20	1.12	1.1.27-S
23	Chrome total	$mg^1 \cdot l^{-1}$	0.10	0.006	1.1.38-S
24	Cadmium	$mg^1 \cdot l^{-1}$	0.005	0.002	1.1.39-S
25	Lead	$mg^1 \cdot l^{-1}$	0.05	0.034	1.1.54-S

A higher rate of iron and zinc is a result of various types of waste and the geological structure of soil. The Table 7 presents the River Ralja water quality in Radinci in the course of 2012. In 2011, out of 17 samples of suspended particles concentration, the concentration of suspended particles was higher than the MPC in 11, ammonia in 1, iron in 10, COC in 15, BOC in 13, zinc in 1, and phenols in 3 samples. It is important to note that other measured parameters were below the MPC, including sulphates, chlorides, phosphates, nitrites, nitrates, sodium, lead, chrome, cadmium, copper, sediment matter, and oxygen. Results of overall analyses are comprehensive and cannot all be presented in this paper. The presence of iron is the consequence of ironworks waste, as well as organic waste which contains iron (blood, waste from slaughter houses, etc.).

Organic waste also results in a higher rate of nitrates, nitrites, ammonium ions and phenols.

Part of results of testing chemical parameters of the River Ralja water quality at the measurement unit M-4 is presented in the Table 7. Testing was executed upon the defined standards. The quality of water is within the legally defined standards for the water of Class II of quality. The measurement unit M-4 is located under the bridge in Radinci.

As presented in the Table 7, there were 7 permanent points (quality monitoring stations) within the execution of the program of surveying the water and sediment quality in the Ralja River basin for establishing sixteen physical and chemical features of the Ralja River water, assumed to often deviate from the legally defined values. Based on the received values, the most frequent deviation from the maximum permitted concentrations (MPC) is registered for the following parameters: dissolved oxygen and % of dissolved oxygen, BOC5, content of suspended articles, COC5, nitrites, iron, phenols, zinc, ammonia ion.

Landfills with solid communal waste in the River Ralja basin

Poor communal waste management is one of the major environmental issues in the Republic of Serbia, mainly resulting from the previous attitude of the society towards waste. High costs, irrational organisation, low service quality and insufficient environmental awareness are the result of an adverse situation in organising waste management. Until several years ago, virtually the only way of managing waste in the Republic of Serbia was disposal at local landfills which, with few exceptions, do not satisfy elementary sanitary and technical and technological conditions. In the previous period, the construction of sanitary landfills has begun in Serbia, and some of them started operating by 2010 (Vranje, Pancevo, Lapovo). (Ministry of Environmental Protection of the Republic of Serbia, 1999)

The national waste management strategy, adopted by the Government of the Republic of Serbia in 2003, represents the foundation for rational and sustainable waste management, including basic EU principles in the area of waste management. The revision of this strategy is in its final phase. The existing landfills – dumps represent sites with a highly negative impact on the living environment. A negative influence on air, ground and surface waters and soil is directly evident. Waste in itself represents a loss of matter and energy, while its collection, treatment and disposal requires a high volume of additional energy and work. (Water Classification Regulation of the Republic of Serbia "Official Gazette of the RS", no. 5/68)

In the course of 2005, the Environmental Protection Agency implemented the project titled “Innovation of the Landfill Cadastre in the Republic of Serbia”. According to the obtained data, 164 landfills used by municipal public utility companies for waste disposal are registered at the territory of the Republic of Serbia. Out of the total number of municipalities, 15 do not dispose of waste at their territory and use landfills of some other municipality. In 2009, the Sector for Control and Monitoring of the Ministry of Environmental Protection composed a registry of illegal landfills at the territory of the Republic of Serbia. The total number of registered locations is around 4500. In most cases, illegal landfills are located in rural areas and are often formed on the river banks and along roads, mainly at slopes and feet of road dykes. (Figure 4, Environmental Protection Agency, 2008).

Figure 4. Places where the samples were taken. (Source: Original)

Such landfills are often inaccessible for removal. The Environmental Protection Agency compiled data on a volume of communal waste and a number of households that generated that waste in the course of 2006. The obtained data differed significantly among municipalities and it was concluded that those estimates were inadequate in most cases, not reflecting the actual situation regarding waste generation. Volumes of communal waste on an annual basis are calculated based on measuring waste in referential municipalities. Based on the results of those measurements, it can be concluded that urban population generates 1kg of communal waste per capita a day on average, compared to 0.7kg generated by rural population. Belgrade generates 1.2kg of waste per capita a day. On average, 0.87kg of communal waste per capita a day is generated at the territory of the Republic of Serbia.

Organisation of hazardous waste management in the Republic of Serbia is at a low level and requires and integral approach in all phases – from the moment of generation, to collection, transportation, treatment, to disposal. A similar problem occurs in the area of the River Ralja basin, where there are facilities for treating specific types of waste (car batteries, electronic and electric waste, used oils, used vehicles). There are no facilities for permanent storage of hazardous waste and temporary disposal is mainly executed at the premises of a company generating it, and very often in an illegal manner, in the profile of surface waters (Figure 5).

Figure 5. Various waste materials at the spring section of the river
(Photo: Djekovic, 2012)

The adoption of the law on waste management and the law on packaging and packaging waste ("Official Gazette of the RS," no. 36/09) provides a legal framework for establishing an integral system of waste, packaging and packaging waste management.

There are several legal landfills for solid communal waste in the River Ralja basin. However, there are also illegal, non-regulated landfills. The government of the republic of Serbia adopted the decision on defining the national environmental protection program in Belgrade, on January 21, 2010.

Upon the decision, many activities have been undertaken in the aim of quality control of the living environment, surface and ground water, landfills for solid communal waste. It is established that the volume of communal waste collected per day is 0.87kg per capita. The conclusion is that around 30.54t of communal waste a day is disposed of in the River Ralja basin.

As this is primarily an agricultural and vacation area, the structure of generated communal waste is somewhat different compared to the structure of communal waste in Serbia in general, as a share of organic waste is significantly higher, while a share of paper, textile, glass, polyethylene, plastic, rubber and metal is much lower. Communal waste mainly consists of waste from households, public areas, Horeca facilities, as well as of construction trash and various other types of cumbersome waste. This fact may represent a huge advantage, as this material is biodegradable and its processing can be used for energy production. In the European Union, this type of waste is used in recycling.

Communal waste landfills often include waste of animal origin from households and meat processing and cattle breeding facilities. This waste consists of scrap meat, bones, skin and other animal parts. This type of waste belongs to the category of hazardous waste and is a source of contamination. Its disposal at communal waste landfills is banned. Local administrations of the communities of Ralja, Mala Ivanca and Mali Pozarevac have registries of the position, volume and structure of communal waste, while other local communities do not.

Around 3,000t of non-fermented pomace, consisting of fruit seeds and peel, are disposed of near the River Ralja annually, accounting for 20% of the total volume of grape and around 900t of wine residue, which contain coagulants and wine yeast. Around 6% of wine residue is generated from a total volume of grape. It means that around 3,900t of organic residue is generated annually and disposed of near the River Ralja. In this type of production, stems, pits, rotten fruit represent waste which is mainly disposed of from production facility premises to the River Ralja.

Many waste materials which should be treated separately, such as waste of animal origin in meat processing, are disposed of at illegal landfills (Figure 4). Illegal landfills for waste of animal origin from mini farms, mini slaughter houses, namely, small business facilities, are present in the River Ralja basin, but they vary in size and operate periodically, due to a method of work and technology.

The River Ralja basin includes several mini farms, so manure and other waste from them also pollute the River Ralja via surface waters, due to a lack of sewage systems.

“Ralja" foundry in Ralja (Sopot) did not generate foundry and industrial waste in 2011, while the type of waste material generated in these facilities in the future depends on several factors.

CONCLUSIONS

The tested samples of water, sediments and emulsified matter from the River Ralja lead to the conclusion that the watercourse is characterised by a strong natural ability of self-purification. Despite evidently present point polluters in the overall river basin, the water along the course is ranked as the Class II and III of quality.

Organic matter of protein and carbon hydrate (monosaccharide) origin was present along the entire course, combined with faecal and other pollutions of organic and non-organic origin. Bacteria, as indicators of polysaccharide substances, were not present. The water temperature showed characteristic seasonal fluctuations, which were relatively high, ranging from 5.4°C in January to 23.6°C in July.

Basic physical and chemical parameters were constantly within a range defined for the Class II and III of quality and included: pH value, five-day biochemical oxygen consumption (BOC_5), concentration of dry residue, iron, ammonia ion and nitrates.

Regular fluctuations of the pH value from 7.8 to 8.2 were registered and the water was constantly slightly alkaline, as expected for this type of wastewaters running off to surface watercourses.

The rate of iron was not elevated, even in periods of higher flow, and was balanced throughout 2011 and 2012. The products of protein substance decomposition (ammonia ion, nitrites and nitrates) were constantly present in the River Ralja water, and their concentration fluctuated significantly, depending on a season. Five-day biochemical oxygen consumption was low and relatively stable, ranging from $1.5mg^{1}\cdot l^{-1}$ O_2 in April 2011 to $52.40mg^{1}\cdot l^{-1}$ O_2 on 13/03/2012, when the MPC was exceeded significantly. Dry residue concentration ranged from $604mg^{1}\cdot l^{-1}$ to $889mg^{1}\cdot l^{-1}$, with high values resulting from strong presence of dissolved salts, except in flooding periods, when it dropped significantly. Ammonia ion concentration fluctuated throughout a year, from $0.20mg^{1}\cdot l^{-1}$to $1.24mg^{1}\cdot l^{-1}$, with the July concentration of $1.24mg^{1}\cdot l^{-1}$significantly above the MPC. Nitrites also fluctuated a lot, from $0.008mg\cdot l^{-1}$ in December to $0.195mg\cdot l^{-1}$ in June, with the July rate nearly four times higher than the MPC for the Class II of quality.

Concentration of nitrites, as the final form of protein substance decomposition, largely depended on the rate of oxygen dissolved in water, necessary for their oxidation, and ranged from $<0.5mg^{1}\cdot l^{-1}$ to $0.9mg^{1}\cdot l^{-1}$, which were regular rates. The highest concentration of orthophosphates was registered in July – $0.477mg^{1}\cdot l^{-1}$, when the water level is the lowest, while the minimum was registered in April – $0.06mg^{1}\cdot l^{-1}$. The oxygen rate decreased significantly at high temperatures, to $2.3mg^{1}\cdot l^{-1}$ in July, which was almost on a verge of threatening hydrobionts. The deficit was minimal in September – $5.6mg^{1}\cdot l^{-1}$, while in other samples the concentration ranged from $8.3mg^{1}\cdot l^{-1}$ to $9.8mg^{1}\cdot l^{-1}$, corresponding to the Class I. Chemical oxygen consumption was within the defined limits, ranging from $4.3mg^{1}\cdot l^{-1}$ to $7.7\ mg^{1}\cdot l^{-1}$ O_2, which was below the

MPC and corresponded to the Class II of river waters. The oxygen regime was slightly disturbed, as in the year before.

Concentration of suspended particles was low, ranging from $1mg^{1}\cdot l^{-1}$to $24mg^{1}\cdot l^{-1}$, which was favourable and pointed to the fact that there was no heavy precipitation in the upstream section of the basin prior to the sampling.

Based on the lab testing results, the conclusion is that toxic substances from this group of parameters (detergents, heavy and toxic metals, evaporable phenols and mineral oils) were not present to a high extent in the River Ralja water and did not threaten this watercourse. Such situation was maintained for several years, which was highly favourable from the environmental aspect.

Concentration of chlorides was extremely high - $179mg^{1}\cdot l^{-1}$, most likely resulting from the geochemical structure of soil, as other tested parameters did not point to a significant influence of sanitary wastewaters. Testing of heavy and toxic metals showed only minimal presence of zinc $0.020mg^{1}\cdot l^{-1}$, copper – $0.002mg^{1}\cdot l^{-1}$ and arsenic – $0.003mg^{1}\cdot l^{-1}$, while lead, cadmium, nickel and mercury were not found in measurable concentrations, which was favourable from the eco-toxicological aspect.

Regarding organic micro pollutants, detergents based on ABS substance and mineral oils are not present, while evaporable phenols are barely detectable, which is important and favourable for the preservation of the water life.

These results indicate that the Ralja waters can be used for both supplying cattle with it and irrigation, without concern over potential negative effects, which is relatively rare with small watercourses.

According to the results of bacteria identification, the following bacteria were mainly present in the River Ralja: Esh. Coli, Enterobacter sp., Citrobacter sp. and Pseudomonas aeruginosa. It is evident that this was the case of only recent faecal pollution. Sulphite-reductive clostridia were constantly present in the Ralja water, but their volume per $1dm^{3}$ of water could not be determined in any of the samples, due to a strong increase of colonies, namely re-swarming of the base, pointing to the conclusion that part of organic matter deposited in the river silt was decomposed in an anaerobic process. The microbiological situation was slightly worse than in 2007.

Based on the testing results, the analysed sample was classified as the Class II of quality upon Kohl. These findings were slightly better than expected, based on results of other tests conducted in September, and did not fully match results on an annual basis. The phosphatase activity index was 1.70, corresponding to the water of the Class II-III.

Resulting from the structural and saprobiological analysis of the bed plankton and faunae and samples of the River Ralja water and sediments in the period of low-level waters, the defined saprobiological status led to the conclusion that the River Ralja waters near Umcari corresponded to the Class II and III of quality in 2011 and 2012.

ACKNOWLEDGEMENTS

This paper was produced within the “New Bioecological Materials For The Protection Of Soil And Waters” project (tp37002) and the “Survey Of Climate Change On The Living Environment: Monitoring Of Adaptation Effects And Mitigation” project (iii 43007), financed by the Ministry Of Education, Science And Technological development of the Republic of Serbia.

REFERENCES

Adamov, I.I., Shpiltskevich, M.A. (1977): Density of planting and harvest of seed tubers, 1.Andjelkovic A., Djekovic V., Milosevic N., Kernalis Đ.J., Milivojevic S., (2013): Analysis of the River Ralja Water Quality, DIT Serbia, Sumarstvo magazine, Vol. 3-4, pp. 59-76, ISBN: 0350-1752 UDC: COBISS.SR-ID 512711324

Andjelkovic, A., Djekovic, V., Milosevic, N., (2014): “Quality Control of the Palic Lake Water and Silt, Sumarstvo magazine, UDK 630*116.64:630*266(497.113), Association of Forestry Engineers and Technicians of Serbia, Belgrade, 3-4, pp. 44-58

Krstic M., Babic V., Kanjevac B., (2013): Contribution to the Insight into Climate and Vegetation Features of the Hill Areas of Serbia, Sumarstvo magazine, COBISS.SR-ID39008263, Association of Forestry Engineers and Technicians of Serbia, Belgrade, 3-4, pp. 113-123

Djekovic, V., (2007): Water Protection University Textbook, Faculty of Forestry, Belgrade, pp. 1-205. ISBN 978-86-7299-131-4. COBISS.SR.ID 139355148.

Djekovic, V., (2004): Drinking water quality and bottled water trade on Belgrade market DIT Serbia. Belgrade, Sumarstvo magazine, Vol.56, iss.pp.49-55.

Djekovic, V., Gajic, G., Letic, Lj.,(2008): The Level of Contamination of the Forest Ecosystem in the Spring of the Barajevska River, Collection of Papers, University of Novi Sad, Faculty of Agriculture, Water Management Department, pp. 132-138.

Dragovic, S., Spalevic, V., Radojevic, V., Cicmil, M., Uscumlic, M., (2012): Importance of chemical and microbiological water quality for irrigation in organic food production. Agriculture and Forestry, 55 (1-4): 83-102, Podgorica.

Djekovic, V., Gajic, G., Andjelkovic, A., Milosevic, N., Kernalis, J., (2010): The water quality in the basin of the Vrla river and its impact on environmental quality, First Serbian Forestry Congress-future with forests Belgrade, 11-13 November.

Letic, Lj., Djekovic, V., Nikolic, V., Andjelkovic, A., Milosevic, N., (2012): Water runoff regime in conditions of beech-fir habitat on the mountain Goc, International Conference on Land Conservation – LANDCOM 1209, Danube Region/Republic Of Serbia.

Letic, Lj., Gajic, G., Djekovic, V., (2008): Production and transportation of suspended deposit in the Gvozdacka River basin at Mt. Goc, Newsletter of the Faculty of Forestry, University of Banja Luka, pp. 25-38.

Djekovic, V., Milosevic, N., Letic, Lj., Gajic, G., Janjic, M., Grujovic, D., Nikolic, V., (2013): Morphological development of regulated rivers, case study of the river toplica. Subject: Acknowledgment of paper reviews and publication.- journals TTEM- Techniques Technologies Education Management No:203./26.12.2012, Vol. 8.No.3.8/9.2013. ISSN 1840-1503 BiH e- mail, ttem bih@vahoo.com

Milosevic, N., Djekovic, V., Andjelkovic, A., Spalevic, V. (2014): Efficiency of wastewater treatment at Bileca wastewater treatment plant in the Republic Srpska – Bosnia and Herzegovina. Forestry [Sumarstvo], 2014 (1-2): 131-147.

Mihailovic, M., (2007): Seliste dam and accumulation, Vrnjacka Banja water supply, Monograph, Mihailovic M. i D. Foundation, p. 282, ISBN. 978-86-906339-3-7 COBISS. SR-ID 141251340

Salama Y., Chennaoui M., Mountadar M., Rihani M., Assobhei O., (2013), The physicochemical and bacteriological quality and environmental risks of raw sewage rejected in the coast of the city of El Jadida (Morocco), Carpathian Journal of Earth and Environmental Sciences, Volume 8, Number 2, p. 39 - 48

The Environmental Protection Agency (2008): Report on the Environmental Conditions in the Republic of Serbia in 2008, the Ministry of Environment and Spatial Planning

The Ministry of Environmental Protection of the Republic of Serbia (1999): Treatment of communal wastewaters, technological and technical overview and analysis of functioning of the existing facilities, proposal for wastewater treatment systems-facilities from the aspect of protecting waters, soil and air of settlements in the Republic of Serbia, pp. 1-563

Water Classification Regulation of the Republic of Serbia (Official Gazette of the RS, no. 5/68)

ZJZ - National Institute of Public Health of Serbia (Zavod za javno zdravlje Srbije).