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IMPACT OF THE CONSTRUCTION SITE OF A PART OF THE BANJA LUKA – DOBOJ MOTORWAY ON THE QUALITY OF WATER IN THE RIVERS VRBAS AND CRKVENA

Pešević Dušica[1], Knežević Nebojša[2]

[1]*Faculty of Natural Sciences and Mathematics, University of Banja Luka, Bosnia & Hercegovina, e.mail dusicapesevic@gmail.com*
[2]*Civil Engineering Institute "IG", Banja Luka, Bosnia & Hercegovina*

ABSTRACT

The paper presents the impact of the construction site of a part of the Banja Luka – Doboj motorway, section 1: Banja Luka – Prnjavor, in the settlement of Miloševac, on the quality of water in the rivers Vrbas and Crkvena. Before the construction of a new bridge, the zero state was determined in the direct vicinity and at locations downstream from the construction site in order to have a realistic picture of impacts of the mentioned construction on the quality of surface waters. Comparison of the data acquired by continual monitoring of a significant number of parameters (total 18) during 12 months and their zero state, i.e. their values before the commencement of construction, gives a realistic overview of impacts of the construction site on the quality of water in nearby surface watercourses. In the case that the execution of civil works proves to have a negative impact on the quality of these rivers, the cause of negative impacts shall be determined and additional measures of prevention, reduction or mitigation of impacts shall be taken.

Key words: *motorway, water quality, monitoring, zero state, impact*

INTRODUCTION

When executing civil works at the considered construction site of a part of the Banja Luka – Doboj motorway, there is a certain number of activities that can cause negative impacts on water quality. With this regard, civil works (removal of the natural covering layer and disturbance of natural feeding directions) are the greatest hazard, followed by building machines (accidental spillage of oil and oil derivatives) and backfilling watercourse bed with building material due to contractor's negligence. Potential negative impacts can be reduced to permissible limits by applying adequate measures that are defined by the environmental permit [1].

Traditional approaches to assessment of the quality of river water are based on comparison between experimentally determined values of parameters and the existing local norms. However, this does not provide a global vision of the spatial and temporal variations of the total quality of water [2]. An analysis of any observed parameter only gives partial information on the total water quality [3]. The quality of surface waters is determined by natural and anthropogenic processes to a great extent. During an annual hydrological cycle, the quality of surface waters depends on many natural and

anthropogenic factors: precipitation, deposits, i.e. erosion of soil in a watershed, population density and development of industry in the watershed [4,5]. The impact of pollutants on river courses depends on: type of pollutants, their concentration in the water and length of exposure to human activities [6]. According to the previous researches we can state that the most prominent pollutants in Vrbas drainage basin and watercourse are industrial and communal waste waters, occurrence of random waste landfills (the so-called "wild landfills"), traffic, agro-chemical agents etc. [7].

Subject sampling comprised water from the Vrbas and Crkvena riverbeds, settlement of Miloševci, in the direct vicinity and at locations downstream from the Banja Luka – Doboj motorway construction site, section 1: Banja Luka – Prnjavor. The purpose of water sampling is monthly monitoring of the quality of water in the rivers Vrbas and Crkvena with the aim of monitoring the impact of works execution on these watercourses.

Knowing and maintaining the quality of watercourses is a good basis both from the aspect of agriculture development and from the aspect of the environmental protection. Monitoring of surface waters represents a very significant factor in the control of water quality and thus the human health protection.

DETERMINING THE QUALITY OF WATER QUALITY IN THE TERRITORY OF THE BANJA LUKA – DOBOJ MOTORWAY CONSTRUCTION SITE IN THE SETTLEMENT OF MILOŠEVCI

Credible determination of the water quality in the in the territory of the Banja Luka – Doboj motorway construction site, in the settlement of Miloševci, required the measurement of a number of parameters at two locations, i.e. from the Vrbas and Crkvena riverbeds.

Full tests of water samples were conducted in accordance with the accredited methods prescribed by BAS/EN, by an accredited laboratory Euroinspekt LLC Osječani, Doboj; the results were synthesised and presented in the form of tables.

In each cycle of tests, the water quality parameters were measuresdas follow:

- temperature,
- pH,
- total dry residue
- suspended solids,
- electrolytic conductivity,
- COD,
- $BOD_{5,}$
- iron,
- manganese,
- cadmium,
- chromium,
- copper,
- nickel,
- lead,
- zinc,
- fats and oils,
- sulphates,
- chlorides.

Sampling frequency was once a month, i.e. a total of 12 times during the year 2016.

MEASURING LOCATIONS

With the aim of analysing the quality of waters in the area of the Banja Luka – Doboj motorway construction site, in the settlement of Miloševci, surface water was sampled and tested in are of the construction site, i.e. its direct vicinity at two locations.

Water sample for quality analysis of the Crkvina river water was taken downstream from a river crossing over this bridge in the settlement of Miloševac (at a location that is closest to the construction site), whereas a water sample for quality analysis of the Vrbas river water was taken downstream from the location where a bridge is constructed and the location of a stone aggregate separation plant of company Niskogradnja, Laktaši.

Figure 1. Vrbas river bed sampling location

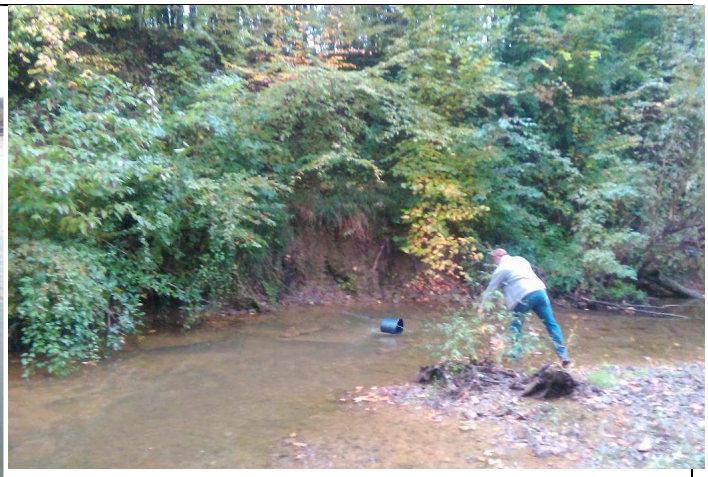

Figure 2. Crkvena river bed sampling location

Coordinates of the taken Vrbas river sample downstream form the location where a bridge is constructed within the motorway, Laktaši, sample 1: 44°54'40.28" N and 17°21'23.73" E (fig. 1). Coordinates of the taken Crkvena river sample, sample 2: 44°54'3.48" N and 17°21'22.56" E (fig. 2).

METHODS OF TESTING

After sampling a specific type of water, composite samples were formed whose temperature and pH were determined on the spot, and the remaining samples were adequately, in line with standard methods, conserved and sent for laboratory analysis.

Results of the analysis of water samples from the rivers Vrbas and Crkvena were commented in line with the Decree on water course classification and categorisation (RS Official Gazette, No. 42/01) [8]. For parameters that belong to the group of general physical and chemical parameters, quality assessment of the tested sample is conducted in line with relevant values for each parameter and related water class. An overview of tested parameters and used methods is given in table 1.

Table 1 List of parameters with test methods

No.	Parameter and unit	Test method	No.	Parameter and unit	Test method
1.	Water temperature, ^oC	BAS DIN 38404-4:2000	10.	Cadmium, mg/m³	BAS ISO 8288:2002
2.	Water pH value	BAS ISO 10523: 2002	11.	Content of chromium, total and hexavalent, mg/m^3	BAS EN 1233:2002
3.	Total dry residue, g/m³	BAS EN 872:2006	12.	Copper, mg/m^3	BAS ISO 8288:2002
4.	Suspended solids, g/m³	BAS EN 872:2006	13.	Nickel, mg/m^3	BAS ISO 8288:2002
5.	Electrolytic conductivity, μScm^{-1}	BAS EN 27888:2002	14.	Zinc, mg/m³	BAS ISO 8288:2002
6.	BOD_5 at 20°C, gO_2/m^3	BAS ISO 5815-2:2004	15.	Lead, mg/m³	BAS ISO 8288:2002
7.	COD from $KMnO_4$, gO_2/m^3	BAS ISO 6060:2000	16.	Fats and oils, mg/m³	EPA 1664-R-A : 1999
8.	Iron, mg/m³	BAS ISO 6332:2000	17.	Sulphates, g/m³	ASTM D 516:2007
9.	Manganese, mg/m³	BAS ISO 6333:2003	18.	Chlorides, g/m³	JUS ISO 9297:1989

Assessments of the environmental and chemical status of surface waters in line with the Law on Waters (RS Official Gazette, No. 50/06) [9] and the Decree on water course classification and categorisation (RS Official Gazette, No. 42/01). According to the standard definitions of the environmental status of water quality and permissible limit values for some quality parameters, all surface waters comprised by the mentioned Decree are classified into five classes, 1 to 5.
According to the environmental quality of water, which must be maintained or achieved by introducing preventive measures and best economic available technologies, the Vrbas river surface course is classified into II watercourse category, and the Crkvena river belongs to I water quality category [8].

MEASUREMENT RESULTS

Based on the results of measurement of tested parameters of surface water quality of the rivers Vrbas and Crkvena at the subject location, results can commented in line with the Decree on water course classification and categorisation (RS Official Gazette, No. 42/01) [8].

Table 2 Measurement results, River Vrbas, downstream from the bridge construction location

	JAN.	FEB.	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Water temperature, °C	5.1	8.3	7.8	11	11.1	19.2	15.5	18	18.3	10.2	9.8	4.1
pH – value	7.56	7.92	8.11	8.08	8.04	8.11	8.21	8.12	7.93	7.86	7.85	7.64
Total dry residue, g/m³	276	293	244	243	264	268	125	120	106	124	286	226
Suspended solids, g/m³	6.4*	3.2*	6.0*	4.0*	10.2*	18.5	20	4.8*	6.3*	2.4*	13.2*	11.9*
Electrolyt. Conductiv.	347*	372*	382*	363*	368*	393*	401*	457*	437*	422*	411*	154*
BOD5, gO_2/m^3	3.0*	8.0**	3.5*	3.0*	3.5*	8.0**	4.8	4.9	4.4	4.0*	4.3	3.9
COD, gO_2/m^3	9.4*	28.5	15.0*	9.0*	11.0*	18.9	12.8*	15.7	12.8*	12.9*	15.8	12.8
Iron, mg/m³	83.8	61.5	80.6	79.5	112.9*	110*	29.5*	32.3*	42.0*	131.0*	69.3*	200.0*
Manganese mg/m³	40.6*	23.1*	36.0*	32.0*	36.9*	34.6*	41.0*	37.3*	44.9*	11.0*	31.9*	25.9*
Cadmium, mg/m³	<0.05	<0.05	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Copper, mg/m^3	1.3	1.9	1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Nickel, mg/m^3	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*
Lead, mg/m³	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc, mg/m³	1.9	3.0	1.6	1.0	1.0	1.3	1.3	1.3	1.0	<0.1	<0.1	<0.1
Fats and oils, mg/m³	<2.5	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7
Sulphates, g/m³	19.6	15.7	20.4	<1.0	17.2	14.3	17.3	17.6	25.3	18.9	32.7	34.7
Chlorides, g/m³	4.8	3.4	4.9	4.8	2.7	2.7	2.0	1.4	3.4	6.8	3.4	3.8

* Values reduced in comparison to the zero monitoring
** Values increased in comparison to the zero monitoring

Although according to the Decree on water course classification and categorisation [8] the Vrbas river must meet the criteria prescribed for II watercourse quality class, the concentrations of major measured parameters at the location satisfy the values prescribed for I watercourse class: total dry residue, manganese, cadmium, chromium, copper, nickel, zinc, lead, fats and oils, sulphates and chlorides. The values of two parameters were within the limits of quality prescribed for II watercourse category, as follow: iron and electrolytic conductivity.

Deviations from the related II water quality class at this measuring location were identified for the following parameters:

- suspended solids – values were within the third class limits (in January, February, March, August, September and November), fourth class (in May and December) and the fifth water quality class (u June and July,)
- BOD_5 - values were within the third water quality class limits (in January, February, March, August, September and November), in the fourth class limits (in May and December), and in the fifth water quality class limits (in June and July)
- COD from $KMnO_4$ - values were within the third class limits (in March, May, July, September, October), and the fourth water quality class (in February, June, August, November and December)

Table 3 Measurement results, River Crkvena, at the location closest to the construction site

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Water temperature, ^oC	0.5	7.4	7.7	12	13.2	19.2	19	18	19.5	9	8.9	1
pH – value	7.34	7.78	7.95	7.97	8.09	8.06	8.22	7.82	7.79	7.81	7.84	7.66
Total dry residue, g/m³	248	242	239	250	262	260	105	103	115.7	106	292	275
Suspended solids, g/m³	7.3*	5.5*	6.9*	6.6*	12.8*	18	8.8*	5.4*	5.5*	4.0*	19.2	20.7
Electrolytic conductivity	391*	268*	312*	339*	362*	364*	431*	442*	415*	384*	408*	426*
BOD5, gO_2/m^3	3.0*	7.5**	3.6*	3.0*	4.0*	9.0**	4.8	4.9	4.8	4.4*	4.2	5.3
COD, gO_2/m^3	9.4*	24.7	12.0*	9.0*	13.5*	14.8*	14.8*	16.8	14.6*	13.6*	14.3*	15.7
Iron, mg/m³	94.4	58.9	90.8	88.6	96.2	99.2	89.7	85.3	98.8	93.0	76.8	67.0
Manganese, mg/m³	76.0	22.9*	64.8	66.0	54.9	55.6	58.9	49.6	70.9	27.0*	24.9*	19.9*
Cadmium, mg/m³	<0.05	<0.05	<0.005	<0.05	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Copper, mg/m^3	1.4	1.8	1.0	1.0	1.0	1.0	1.0	1.2	1.3	<1.0	<1.0	<1.0
Nickel, mg/m^3	<0.05	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lead, mg/m³	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc, mg/m³	2.3	2.9	1.6	1.8	1.4	1.5	1.4	1.3	1.2	1.0	1.0	1.2
Fats and oils, mg/m³	<2.5	<2.5	<2.7	<2.7	<2.7	<2.7	<2.7	<2.5	<2.7	<2.5	<2.5	<2.7
Sulphates, g/m³	36.0	24.8	26.8	1.24	27.1	25.5	43.1	40.0	25.6	13.6	36.1	37.8
Chlorides, g/m³	7.8	4.4	6.6	4.07	5.4	4.7	7.5	16.9	10.9	12.2	8.82	9.43

* Values reduced in comparison to the zero monitoring
** Values increased in comparison to the zero monitoring

In comparison to the zero monitoring, i.e. values of the analysed parameters before the construction of a bridge on the river Vrbas, we can draw a conclusion that the values of a majority of monitored parameters in 2016 were in the same or a better water quality class, except for BOD_5, whose values were higher in two samples (in February and June) (Table 2).

The analysis of water samples from the river Crkvena showed that a majority of parameters stayed within the limits prescribed for I watercourse category [8] during the entire year: pH value, total dry residue, iron, cadmium, chromium, copper, nickel, zinc, lead, fats and oils, sulphates and chlorides.

Deviations from the related first water quality class at this measuring location were identified for the following parameters:

- electrolytic conductivity – values were within the second water quality class limits in the following months: July, August, September, November and December
- suspended solids - values were within the third class limits (u January, February, March, April, July, August and September), fourth class (u May) and the fifth water quality class (in November and December)
- BOD_5 - values were within the second class limits (in January, March, April and May), the third class (in July, August, September, October, November and December), and in the fourth water quality class limits (in February and July)
- COD from $KMnO_4$ - values were within the second class limits (in January and April), the third class (in March, May, June, September, October and November), and the fourth water quality class (in February, August and December)
- Manganese – whose values stayed within the second water quality class limits in the following months: January, March, April, May, June, July and September.

The values of certain parameters comprised by monitoring during the year 2016 in the river Crkvena were lower than the zero monitoring, notably: suspended solids, electrolytic conductivity, BOD_5, COD and manganese.

The values of suspended solids during the zero monitoring were within the fifth water quality class, the values of electrolytic conductivity and COD within the fourth class, BOD_5 values within the third class, and the values of manganese within the second water quality class. Only the values for BOD_5 were increased in two samples (in February and June) in comparison to the zero monitoring, meaning in comparison to the recorded values before the commencement of works at the mentioned construction site (Table 3).

Water temperature is a significant parameter from the aspect of solubility of oxygen and other gases from the air in water; in increase in temperature also increases the speed of oxygen demand (biochemical oxidation).

In the analysed samples of water, the highest temperature of surface waters was registered in the sample of water from the river Crkvena in the month of September when it was 19.5 ^{0}C, whereas in the river Vrbas temperature rose up to 19.2 ^{0}C, registered at the mentioned measuring location in the month of June 2016.

A measured pH value in the samples of surface water taken at the measuring location 1 (samples of water from the Vrbas river bed at a location downstream from the location where a bridge on this river is built) ranged between 7.56 and 8.21, and at the measuring location 2 (from the Crkvena river bed at a location that is closest to the construction site) pH value ranged from 7.34 to 8.22, which is within the limits for the first surface watercourses quality class amounting 6.8-8.5. It should be stressed that the measured pH values in the river Vrbas (measuring location 1), in May and June were higher than the zero monitoring, whereas in the river Crkvena all registered pH values remained within the permitted limit values for the first water quality class, with no significant changes.

The highest registered value of BOD_5 was 8 gO_2/m^3 in a sample taken from the river Vrbas and 9 gO_2/m^3 in a sample taken from the river Crkvena, where both values were registered in the month of June. Both values belong to the fourth water quality class according to the mentioned Decree [8], whereas during the zero monitoring the values of BOD_5 were within the third water quality class. Biochemical oxygen demand (BOD_5) represents a quantity of oxygen consumed by microorganisms to decompose organic substances in the water; it is to say a quantity of oxygen needed to perform biological oxidation of present degradable water elements.

Decomposition of organic substances in water consumes oxygen so that the quantity of oxygen is reduced in polluted waters. A decrease in the quantity of dissolved oxygen as a consequence of the decomposition of organic substances can jeopardise water life through disturbances in the environmental balance in the water. Large quantities of organic substances (microbes and organic waste that decay) in the water represent a potential hazard to water ecosystems and human health [10].

It is a known fact that a high biochemical oxygen demand caused by a high level of organic pollution most frequently generated as a consequence of discharging poorly treated or untreated waste waters.
A noticeable problem with heavy loading of the Vrbas river watercourse with communal and other waste waters has existed for a longer period; it has been registered at the measuring profiles last ten years, as documented in the reports of Institute for Waters, Bijeljina, that implements regular monitoring of the quality of surface waters in Republika Srpska [11].

Still, the amounts of BOD5 of 8.0 $gO2/m^3$, as registered in the river Vrbas, and 9.0 $gO2/m^3$, as registered in the river Crkvena, downstream from the subject construction site, are very worrying and demand a greater attention to their cause in the oncoming period, should such high concentrations repeat.

The pollution of watercourses jeopardises not only the living world therein, but has a direct impact on the population, given the impact that the surface watercourses have on the underground water body among other things.

CONCLUSION

Results of measuring the quality of water at two measuring locations in the area of the Banja Luka – Doboj motorway construction site, in the settlement of Miloševci, lead to a conclusion that no major changes in comparison to the zero monitoring have occurred, it is to say in comparison to the values of analysed parameters prior to the bright construction commencement. Water quality for a majority of the total of 18 tested parameters meets the prescribed I water quality class for the river Crkvena, i.e. II water quality class for the river Vrbas, in line with the Decree on water course classification and categorisation (Republika Srpska Official Gazette, No. 42/01).

In comparison to the zero monitoring, we can draw a conclusion that the values of a majority of monitored parameters, during the year 2016, were in the same or a better water quality class, except for BOD_5, whose values were higher in two samples in both rivers. The significance of determining a water quality level in the rivers Vrbas and Crkvena in the construction site area, i.e. its direct vicinity, and comparison against the zero monitoring, lies in the observation of possible negative impacts of the construction site on the quality of water in the mentioned rivers in order to take adequate measures to prevent, reduce or mitigate further pollution.

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