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IMPACT ANALYSIS OF THE BANJA LUKA-DOBOJ MOTORWAY CONSTRUCTION ON THE QUALITY OF WATERCOURSES WITH A LOWER RECEIVING CAPACITY

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ABSTRACT

Prevention of the surface water quality deterioration as a result of motorway construction or similar anthropogenic activities is certainly a rather more demanding task relating to watercourses with lower flow rates than larger watercourses. The paper presents the impact of part of the Banja Luka - Doboj motorway construction site, notably section 1: Banja Luka - Prnjavor, in Miloševci and Hrvaćani, on the Crkvena river water quality. The Banja Luka-Doboj motorway, with a length of 71.91 km, represents a key regional connection in the Republika Srpska, Bosnia and Herzegovina. It will connect the Gradiška - Banja Luka motorway (E-661) to Corridor 5c.

Conducted sampling included the Crkvena river water, a right-bank tributary of the Vrbas river, in the Miloševci settlement, and at a new measuring point along the Crkvena River, at the culvert location in the settlement of Hrvaćani, near the motorway construction site. The goal of water sampling is monthly Crkvena river water quality monitoring in order to keep track of the of newly built motorway section's impact on this watercourse in the Miloševci settlement; the purpose of water sampling at a new measuring point in Hrvaćani is to control the Crkvena river water quality before the commencement of works at this location so that the impact of same on this watercourse could later be followed up.

Comparison of the data acquired by continual monitoring of a significant number of parameters (total 18) during 12 months with their zero state, i.e. their values before the commencement of construction, gives a realistic overview of impacts of the construction site on the Crkvena river water quality.

Keywords: *impact, construction, motorway, water quality, monitoring*

INTRODUCTION

The construction of roads and related infrastructure, without proper understanding of functional and environmental relationships, can be accompanied by serious environmental disturbances, which can take a long time to restore ecological balance. Negative impacts on water quality can be caused by construction works (removal of the natural cover layer and disturbance of natural recharge routes), then construction machinery (accidental spillage of oil and oil derivatives), as well as backfilling the

watercourse with construction material due to contractor's negligence or the need to narrow water channels [1]. The construction activity can pose a risk both to the physico-chemical and ecological quality of the aquatic environment [2,3]. In this context, it is important to understand the potential impacts of construction activity and undertake comparing pre-construction, during-construction and post-construction water quality data. Water pollution sources can cause increased sedimentation, changes in biological activity in watercourses and on their banks, as well as changes in chemical composition in terms of water contamination due to oil spills, exhaust emissions, pavement and tire wear, metal corrosion, etc. [4,5]. However, some studies have shown that construction activities incorporating best management practices (BMPs) can be conducted without lasting detrimental effects on water quality [6].

Implementing best management practices (BMPs) for future highway construction depends on a comprehensive understanding of environmental impacts from current construction methods [7]. For decades, it has been known that the physical, chemical and biological impacts generated by motorway construction are serious enough to justify the application of various environmental control measures [8]. In the construction phase, much of the environmental impact problem can be successfully addressed by qualitative monitoring of activities and verification of compliance with appropriate work procedures [9].

Environmental monitoring is conducted to determine the extent to which construction works can adversely affect the environment. Keeping track of individual environmental quality parameters is equivalent to controlling the quality of works (zero state = previous tests, periodic measurements = ongoing quality control) [10]. Monitoring is an activity aimed at the recording and measuring of all environmental changes in the construction and exploitation phases. Water quality monitoring before and during the construction of Banja Luka - Doboj motorway section is in line with the recommendations listed in the environmental impact assessment and environmental permit, which determine the parameters, as well as the quantity and frequency of sampling [11].

Negative impacts on the quality of ground and surface water can be avoided by careful and controlled organisation of the construction site and the application of protective measures during construction, as well as through internal drainage and treatment of wastewater generated during motorway construction. The impact of pollutants on the water quality of a water recipient, in addition to the type and amount of these pollutants, depends on the receiving power of same. For this reason, special attention should be paid to smaller watercourses, as is the case with the Crkvena river, a tributary of the Vrbas river, as rivers with a lower flow rate are known to have a lower possibility of auto purification, that is, a higher risk of disturbing the ecological balance. In order to analyse the water quality in the Banja Luka - Doboj motorway construction site area, sampling included the Crkvena river water in the settlement of Miloševci, where the motorway was already built, and a new measuring point on the same river, at the location of a culvert in the settlement of Hrvaćani near the Banja Luka - Doboj motorway construction site, section 1: Banja Luka - Prnjavor, where construction works were still ongoing during water sampling. Coordinates of the Crkvena river water sample taken in the settlement of Miloševac, sample 1: 44°54'3.48"N and 17°21'22.56"E. Coordinates of the Crkvena river water sample taken at the culvert in the settlementt of Hrvaćani, sample 2: 44°52'2.05"N and 17°25'55.43"E. If construction works are proven to have a negative impact on this river's water quality, the cause of the negative impact is determined and additional measures are applied to prevent, reduce or mitigate same in accordance with the requirements listed in the Environmental Permit and the approved monitoring plan mentioned in the Environmental and Social Management Plan during construction.

MATERIALS AND METHODS

After sampling a certain type of water, composite samples were formed in which the temperature and pH were determined on site, and the remaining samples were adequately preserved by standard methods and sent for laboratory analysis.

The Crkvena river water sample analysis results were commented in accordance with the Regulation on watercourse classification and categorisation (RS Official Gazette, 42/01) [12]. For the group of general physico-chemical parameters, the quality of tested water sample is assessed based on relevant values for each parameter and related water class. The tested parameter and applied methods are listed in Table 1

Table 1. List of parameters with test methods

Ord. no.	Parameter and unit	Test method	Ord. 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.	Chromium content, 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.	Grease 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

The Crkvena river water sample analysis results were commented in accordance with the Regulation on watercourse classification and categorisation (RS Official Gazette, 42/01) [12]. For the group of general physico-chemical parameters, the quality of tested water sample is assessed based on relevant values for each parameter and related water class. The tested parameter and applied methods are listed in Table 1.

MEASUREMENT RESULTS

The testing comprised basic groups of physico-chemical parameters of water samples; the acquired measurement results were compared with limit values defined by the Regulation on water classification and watercourse categorisation (Republika Srpska Official Gazette, 42/01) [12]. According to the normative definitions of ecological status of water quality and permissible limit values for individual quality parameters all surface waters covered by the aforementioned Regulation are classified into five classes, from 1 to 5. n accordance with this Regulation, the Crkvena river belongs to the 1st watercourse category.

All water sample tests were done in accordance with the accredited methods prescribed by BAS/EN, by the accredited laboratory Euroinspekt, d.o.o. Osječani, Doboj; the results were systematised and presented in tables (tables 2 and 3). Sampling was done once a month, from January to September, during 2018.
Results obtained from the Crkvena river water sample analysis in the settlement of Miloševci (Table 2) show that the watercourse quality ranges from the first to the fifth watercourse class in relation to individual parameters.

Parameters that do not comply with the values of 1st watercourse class, into which the Crkvena river is classified according to the Regulation on water classification and watercourse categorisation [12] are most frequently as follow: suspended solids, electrolytic conductivity, BOD_5, COD, iron and manganese. For certain parameters were acquired even lower values that classify the concerned watercourse into a higher quality class in comparison with zero monitoring.

Results obtained from the Crkvena river water sample analysis in the settlement of Hrvaćani, at the location of a culvert, (table 3) ranges from the first to the third watercourse class in relation to individual parameters. However, in comparison with zero monitoring most parameters comply with the same watercourse quality class; for certain parameters were acquired even lower values that classify the concerned watercourse into a higher quality class in comparison with zero monitoring (table 3).

Table 2. Measurement results of the Crkvena river water quality, in the settlement of Miloševci

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**
Water temperature,ºC	4.0	2.5	7.61	12.0	18.0	18.8	21	14	20
pH value	7.94	7.92	7.81	7.92	8.14	7.96	8.2	7.83	7.89
Total dry residue g/m³	228	243	225	174	292	296	226	289	221
Suspended solids g/m³	29.0	24	21.0	2.0*	4.0*	3*	3*	3*	2
Electrolytic conductivity	306*	348*	238*	374*	419*	447*	512*	507*	511
BOD5, gO_2/m^3	4.48	4.21	3.95	1.51*	1.92*	2.3*	2.6*	2.3*	2.1
COD, gO_2/m^3	13.0*	13.8*	10.6*	<6.0*	<6.0*	<6.0*	<6.0*	<6.0*	<6.0
Iron, mg/m³	96.0	94	86.5	98.7	92.5	96	86	89	64
Manganese, mg/m³	41.0*	99	<0.01	<0.01*	97	44*	62	75	89
Cadmium, mg/m³	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chromium, mg/m^3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper, mg/m^3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Nickel, mg/m^3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc, mg/m³	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Lead, mg/m³	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Grease and oils, mg/m³	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7
Sulphates, g/m³	29.64	35.2	21.95	37.76	46.8	48.8	46.2	47.2	44.7
Chlorides, g/m³	6.01	10.3	6.01	8.02	17.7	15.9	15.9	17.9	19.8

* Values lower in relation to zero monitoring

Table 3. Measurement results of the Crkvena river water quality, in the settlement of Hrvaćani

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**
Water temperature, ºC	4.5	3.0	7.72	10.5	17.0	19.0	20.5	14.0	19.0
pH value	7.92	7.92	7.82	7.94	7.73	7.60	8.05	7.82	7.86
Total dry residue g/m³	230*	252*	271*	220*	342	252*	296*	288*	280
Suspended solids, g/m³	4.9	4.8	24.0	3.2	5	5	4	4	3
Electrolytic conductivity	311*	337*	263*	378	448	417	468	465	450
BOD5, gO_2/m^3	3.70	3.53	4.28	1.78*	2.02	2.5	1.1*	1.3*	1.8
COD, gO_2/m^3	14.1	14.0	11.3	1.01*	<6.0*	<6.0*	<6.0*	<6.0*	<6.0
Iron, mg/m³	260	293	211	271	90.4*	98*	258	266	254
Manganese, mg/m³	53.0*	154	<0.01	26.0*	186	49*	<0.01*	<0.01*	<0.01

Cadmium, mg/m³	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chromium, mg/m^3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper, mg/m^3	<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	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc, mg/m³	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Lead, mg/m³	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Grease and oils, mg/m³	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7
Sulphates, g/m³	33.72*	42.44*	23.15*	46.94*	48.4*	34.8*	43.3*	44.7*	47.3
Chlorides, g/m³	6.34	11.1	6.94	6.68	7.9	7.9	11.3	14.0	19.3

* Values lower in relation to zero monitoring

Results obtained from the Crkvena river water sample analysis in the settlement of Hrvaćani, at the location of a culvert, (table 3) ranges from the first to the third watercourse class in relation to individual parameters. However, in comparison with zero monitoring most parameters comply with the same watercourse quality class; for certain parameters were acquired even lower values that classify the concerned watercourse into a higher quality class in comparison with zero monitoring (table 3).

DISCUSSION

Although pursuant to the Regulation on water classification and watercourse categorisation [12] the Crkvena river must comply with the parameters prescribed for the first watercourse quality class, the results analysis shows that the values of some parameters ranged within the limit values prescribed for the second and third watercourse quality classes, and the values of suspended solids in three measurements had same values characteristic of even the fifth quality class. Parameters that deviated from the belonging 1st water quality class at the measurement location in Miloševci are as follow:

- electrolytic conductivity – values ranged within the second water quality class limit values in January, May, June, July, August and September
- BOD_5 – values ranged within the second water quality class limit values u July, August and September, and the third quality class in January, February and March
- manganese - values ranged within the second water quality class limit values in a majority of sample analyses: u February, March, May, July, August and September
- COD - values ranged within the second water quality class limit values (u April) and the third quality class (in January and March),

Parameters that deviated from the belonging 1st water quality class at the measurement location in Hrvaćani are as follow:

- suspended solids – values ranged within the second water quality class limit values during all nine months of water quality monitoring
- total dry residue – values ranged within the second water quality class limit values only in the month of May, while the other two measurements showed the values characteristic of the first water quality class
- electrolytic conductivity – values ranged within the second water quality class limit values during the following months: April, May, June, July, August, September

- BOD_5 - values ranged within the second water quality class limit values during the following months: January, February, March, May and June)
- COD from $KMnO_4$ - values ranged within the third water quality class limit values (in January, February and March)
- iron – the measured values ranged within the third water quality class limit values (in January, February, March, April, July, August and September)
- manganese - values ranged within the second water quality class limit values (u January), as well as within the third water quality class values (February, March and May)

However, in comparison with zero monitoring most parameters comply with the same watercourse quality class, and for certain parameters were acquired even lower values in comparison to zero monitoring (tables 2 and 3). The result analysis shows that the motorway construction works do not affect the Crkvena river quality. Their quality is predominantly affected by weather conditions, residential wastewater discharged without prior treatment, washing off from surrounding agricultural areas, as well as wild landfills located on the banks of the concerned watercourse [13].

CONCLUSION

Water quality monitoring before and during road construction, and ensuring the conditions for timely application of additional protective measures can prevent water pollution during the construction period, but also later, during its exploitation. This paper analyses the Crkvena river water samples in order to monitor the impact of Banja Luka - Doboj motorway construction site, section 1: Banja Luka - Prnjavor, on the watercourse in the settlements of Miloševci and Hrvaćani.

The sampling frequency was once a month, from January to September during 2018; the analysis covered 18 parameters. Comparison of the data acquired in continuous monitoring with their zero state, i.e. their value before the construction commenced gives a realistic picture of the construction site impact on the construction site impact on Crkvena river water quality.

In January, February and March were measured the highest values for individual parameters, with BOD_5 and COD values ranging within the third watercourse quality class limits, and measurement results for suspended solids, in the same period, reaching limit values characteristic of the worst, fifth, watercourse quality class. However, in comparison with zero monitoring, most parameters comply with the same watercourse quality class, and for certain parameters were acquired even lower values in comparison to zero monitoring.

The result analysis shows that the motorway construction works do not affect the Crkvena river water quality; its quality is predominantly affected by weather conditions, residential wastewater discharged without prior treatment as well as solid wate disposed of in illegal landfills on the banks of same.

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