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ASSESSMENT OF WATER QUALITY DURING THE FLOODS IN MAY 2014, SERBIA

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Abstract: Floods are considered to be the most common natural disaster which causes more destructive effects than other natural disasters including loss of human life, property and infrastructure damage, as well as a negative impact on social and economic development. Besides these consequences, floods also affect water quality. The aim of this paper is to present water quality impairment caused by the floods in Serbia in May 2014. The parameters of water quality were measured 13 times in 2014 (12 ordinary monthly measurements and one extraordinary measurement during the flood) in hydrological stations Ostružnica and Šabac (on the river Sava) and Badovinci (on the river Drina). The Canadian Water Quality Index (CWQI) was used for water quality assessment. This method calculates the overall water quality and the water quality for specific conditions and purposes including: drinking, aquatic habitats, recreation, irrigation, and livestock. Water quality decline was recorded in all the stations in overall water quality as well as for specific uses. Turbidity and heavy metals values were tens of times higher than normal ranges. The most drastic example was Al with the values which were thousand(s) of times higher than the objective.

Keywords: Canadian Water Quality Index; floods; River Drina; River Sava; Serbia

Introduction

Floods are considered to be the most common natural disasters in the world (Marfai, Sekaranom, & Ward, 2015), and in Serbia as well (Gačić, Bošković, & Raković, 2013). The consequences of floods are numerous and include: damage of transportation and communication, destruction of public facilities and energy supplies, damage of property, health-risk consequences as well as loss of human lives (Gačić et al., 2013; Kuntiyawichai, Schultz, Uhlenbrook, Suryadi, & Van Griensven, 2011; Radosavljevic, Belojevic, & Pavlovic, 2017).

In addition to the direct consequences, the destructive effect of floods is also accompanied by serious environmental damage and the pollution of waters (Ciesielczuk, Kusza, Poluszyńska, & Kochanowska, 2014; Duan et al., 2016; Everett, Lamond, Morzillo, Matsler, & Chan, 2018; Gačić et al., 2013; International Commission for the Protection of the Danube River [ICPDR], 2009; Middelmann-Fernandes, 2010; Mogollón, Villamagna, Frimpong, & Angermeier, 2016; Mynett & Vojinović 2009; Shesterkin, 2016; Tsuzuki, 2015). Pollution due to flooding is caused by different sources: industries, households, as well as floodwaters stagnation (Dang, Babel, & Luong, 2011). Liquid fuels which

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*Corresponding author, e-mail: d.jakovljevic@gi.sanu.ac.rs escape from storage tanks, damage to supply lines, industrial enterprises, sewage treatment, and chemical plants or filling stations can lead to the contamination or the loss of biological diversity in waters (ICPDR, 2009). Highly toxic substances, including heavy metals and pesticides are released into the water (Krausmann & Mushtaq, 2008). Floods are followed by increased discharges which lead to the transfer of heavy metal pollutants associated with particulate matter, especially in severely polluted catchments (Ciszewski & Grygar, 2016). Pollution by heavy metals in the mines with rocks which reach the surface and which are washed by precipitation also occurs (Babić Mladenović, 2009). In acidic waters, the enhanced input of rainwater may dilute acidity and cause the hydrolysis of Fe^{3+} ions, followed by the precipitation of Fe oxides and conversion of dissolved heavy metals to solid particles. In this way, floods change river water chemistry (Ciszewski & Grygar, 2016). Agricultural pollution by flood also affects water quality (Su et al., 2016; Zhang, Gao, Wang, & Chen, 2013). Huang and Xiang (2015) claimed that the contribution of total nitrogen and total phosphorus from non-point sources in the flooding seasons can reach 70%.

Between 2007 and 2016, 13 floods in Serbia were recorded. These floods had serious consequences including: 58 deaths, 90,000 affected people and economic damage of US $ 2,148,000 (Radosavljevic et al., 2017). The most catastrophic floods occurred in Serbia, Bosnia and Herzegovina, and Croatia, in May 2014. These floods in Serbia which occurred from 12 to 19 May 2014 caused about 40 dead, and forced tens of thousands of people to leave their home. They also caused houses, roads, and railways submerging and landslides burying the houses (ICPDR & International Sava River Basin Commission [ISRBC], 2015; Shepherd, 2014).

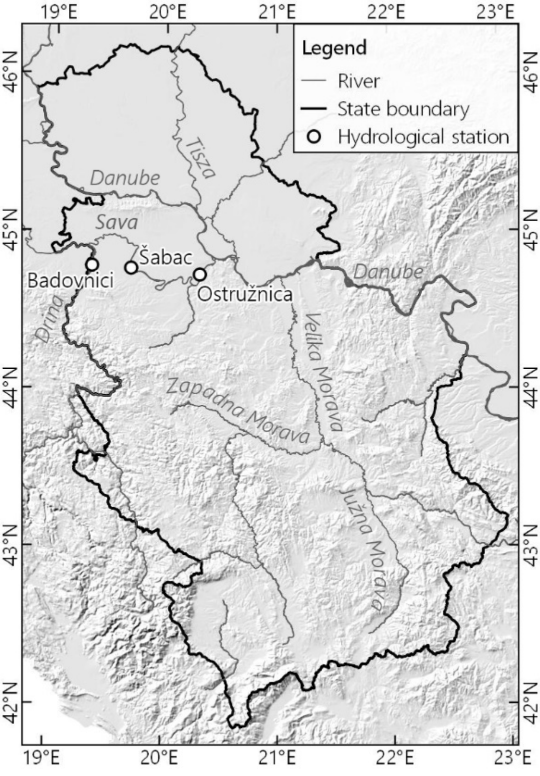


Figure 1. Study area with location of the hydrological stations.

The flooding in May 2014 significantly changed the water quality by decreasing the amount and discharge rate of urban wastewaters but at the same time, by introducing contaminants from the nearby fly ash field disposal (near Obrenovac, settlement which suffered devastating effect of flood) into the Sava River by runoff (Aborgiba et al., 2016). This paper aims to present the effects of the mentioned flood on water quality of the rivers Sava (hydrological stations Šabac and Ostružnica) and Drina (hydrological station Badovinci).

Data and methodology

In order to assess water quality, physical, chemical, biological, and microbiological parameters were measured in the following hydrological stations (Figure 1): Ostružnica and Šabac (on the river Sava) and Badovinci (on the river Drina). The total number of measurements was 13 for each station (12 ordinary monthly measurements and one extraordinary during the floods, on 17 May 2014). The data were obtained from Yearbook III Water Quality for 2014 (Serbian Environmental Protection Agency [SEPA], 2015) and from the Report about extraordinary sampling of the rivers Sava and Drina (SEPA, 2014).

Water Quality Index (WQI) methodology is often used for surface water quality assessment (Srivastava & Kumar, 2013; Tunc Dede, Telci, & Aral, 2013; Venkatramanan, Chung, Lee, & Park, 2014). WQI is a dimensionless single number which is calculated from a large number of water quality parameters (Tunc Dede et al., 2013). There are many variants of WQI, such as: Oregon Water Quality Index (OWQI), Aquatic Toxicity Index (ATI), Overall Index of Pollution (OIP), Universal Water Quality Index (UWQI) (Tunc Dede et al, 2013), Serbian Water Quality Index (SWQI) (Milanović Pešić, Jakovljević, & Milijašević Joksimović, 2020; Milijašević Joksimović, Gavrilović, & Lović Obradović, 2018; Mladenović-Ranisavljević & Žerajić, 2018; Walker, Jakovljević, Savić, & Radovanović, 2015), Agri-Food Water Quality Index (AFWQI) (Blessing & Benedict, 2017), Canadian Water Quality Index (CWQI) (Baghapour, Nasseri & Djahed, 2013; Jakovljević, 2012; Jakovljević & Lozanov-Crvenković, 2015; Tunc Dede et al., 2013).

The CWQI methodology was used for water quality assessment in this study. The advantage of this methodology compared with many other variants of WQI is a larger number of parameters and information about heavy metal pollution. Further, besides the overall water quality, CWQI provides information about water quality for specific purposes and uses: drinking water, aquatic habitat, livestock, irrigation, and recreation (Jakovljević & Lozanov-Crvenković, 2015).

The assessment of water quality during the flood was achieved by comparing the results between CWQI with the total number of measurements and CWQI with ordinary measurements. CWQI could not be applied for the assessment of water in just one measurement (at least four measurements are necessary), and it is the main limitation of this index.

The CWQI has been developed by the Canadian Council of Ministers of the Environment, based on the British Columbia Ministry of Environment formulation in 1995 (Canadian Council of Ministers of the Environment [CCME], 2005; Tunc Dede et al., 2013). The CWQI is calculated by using the following parameters: Temperature, Conductivity, Color, Turbidity (Turb), Dissolved Oxygen (DO), pH, Alkalinity (Total Alkalinity), Calcium (Ca), Sodium (Na), Magnesium (Mg), Potassium (K), Sulphate (SO_4^{2-}), Chloride (Cl^-), Fluoride (F^-), Dissolved Organic Carbon (DOC), Phosphorus (P), Nitrate, Nitrite (NO_3^-, NO_2^-), Nitrogen (N), Silicon Dioxide (SiO_2), Aluminum (Al), Arsenic (As), Barium (Ba), Beryllium (Be), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Mercury (Hg), Lithium (Li), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Lead (Pb), Selenium (Se), Strontium (Sr), Vanadium (V), and Zinc (Z) (CCME, 2005). Most of these parameters have their lower and/or upper objectives defined (Table 1). This methodology also enables the calculation of index in the case of missing some parameters.

Table 1
CWQI parameters with upper and/lower values

		Overall		Drinking		Aquatic		Recreation		Irrigation		Livestock	
Variables	Units	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Color	TCU		15		15								15
Turb	NTU		1		1								
DO	mg/l	9.5				9.5							
pH		6.5	8.5	6.5	8.5	6.5	9	5	9				
Ca	mg/l		1000										1000
Na	mg/l		200		200								
SO_4^{2-}	mg/l		500		500								1000
Cl^-	mg/l		110		250						110		
F^-	mg/l		1		1.5		1.2				1		1
NO_3^- NO_2^-	mg/l		100										100
Al	mg/l		0.005				0.005				5		5
As	mg/l		0.005		0.025		0.005				0.1		0.025
Ba	mg/l		1		1								
Cd	mg/l		0.005		0.005						0.0051		0.08
Cr	mg/l		0.001		0.05		0.001				0.0049		0.05
Cu	mg/l		0.002		1		0.002				0.2		0.5
Fe	mg/l		0.3		0.3		0.3				5		
Hg	µg/l		0.003		1		0.1						0.003
Mn	mg/l		0.05		0.05						0.2		
Mo	mg/l		0.073				0.073						
Ni	mg/l		0.025				0.025				0.2		1
Pb	mg/l		0.001		0.01		0.001				0.02		0.05
Zn	mg/l		0.03		5		0.03				1		50

Note. Adapted from "Environment, Climate Change and Municipalities: Canadian Water Quality Index 1.0 Calculator" by Canadian Council of Ministers of the Environment, 2005 (https://www.gov.nl.ca/eccm/waterres/quality/background/cwqi/). Copyright 2005 by CCME. Adapted with permission.

Canadian Water Quality Index 1.0 Calculator (EXCEL application) was used for the calculation in this methodology (CCME, 2005). CWQI is based on three factors of water quality that relate to water quality objectives:

- Scope (F_1)—The number of water quality variables that do not meet objectives in at least one sample ("failed variables"), which represents the ratio between the number of failed variables and the total number of variables;
- Frequency (F_2)—The number of individual measurements that do not meet objectives ("failed tests"), which represents the ratio between the number of failed tests and the total number of tests;
- Amplitude (F_3)—The amount by which failed test values do not meet objectives. F_3 is calculated in three steps:
  - The number of times by which the value of variable is greater (or lower, when the objective is a minimum) than the objective is termed as "excursion";
  - The collective amount is calculated by summing the excursions of individual tests from their objectives and dividing it by the total number of tests (both those meeting objectives and those not meeting objectives). This ratio is referred to as the normalized sum of excursions, or *nse*;

– F_3 is calculated by an asymptotic function that scales the normalized sum of the excursion from objectives (*nse*) in the range between 0 and 100.

Once all the factors have been obtained, the index itself can be calculated by summing the three factors. With this model, the index changes are in direct proportion to the changes in all the three factors:

$$CWQI = 100 - \left(\frac{\sqrt{F_1^{\ 2} + F_2^{\ 2} + F_3^{\ 2}}}{1.732} \right) \tag{1}$$

For each CWQI range a descriptive quality indicator has been defined (CCME, 2005), with the following ranges:

- *Excellent* (95–100)—there is no threat to the water quality; conditions are very close to natural or pristine level;
- *Good* (80–94)—there is a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels;
- *Fair* (65–79)—water quality is usually protected but occasionally threatened; conditions sometimes depart from natural or desirable levels;
- *Marginal* (45–64)—water quality is frequently threatened; conditions often depart from natural or desirable levels;
- *Poor* (0–44)—water quality is almost always threatened; conditions usually depart from natural or desirable levels (Baghapour et al., 2013; CCME, 2005).

Results and discussion

The results derived from the total measurements (ordinary and extraordinary during the flood) show a decline in water quality in comparison with the results derived only from ordinary measurements in all the stations (Figure 2). The highest decline is recorded for Ostružnica station (Table 2 and 3) in overall water quality (from marginal to poor), drinking (from good to marginal), irrigation (from excellent to fair), as well as water for livestock (from excellent to good). Less impairment is also recorded in CWQI for aquatic habitat (from 34 to 21).

Table 2
CWQI for Ostružnica station (ordinary measurements)

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	46	86	34	100	95	100
Categorization	Marginal	Good	Poor	Excellent	Excellent	Excellent
F_1 (Scope)	47	21	64	0	9	0
F_2 (Frequency)	33	11	48	0	1	0
F_3 (Amplitude)	73	5	82	0	0	0
Variables tested	19	14	11	1	11	12
Variables failed	9	3	7	0	1	0
Most failed tests	Cr, Cu, Pb	Turbidity	Cr, Cu, Pb	None	Cr	None
Highest *nse*	Al	Fe	Al	None	Cr	None

Table 3
CWQI for Ostružnica station (ordinary and extraordinary measurements)

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	33	64	21	100	78	90
Categorization	Poor	Marginal	Poor	Excellent	Fair	Good
F_1 (Scope)	58	36	82	0	36	17
F_2 (Frequency)	35	13	51	0	4	1
F_3 (Amplitude)	94	49	96	0	12	1
Variables tested	19	14	11	1	11	12
Variables failed	11	5	9	0	4	2
Most failed tests	Cr, Cu, Pb	Turbidity	Cr, Cu, Pb	None	Cr	Cr, Al
Highest *nse*	Al	Turbidity	Al	None	Cr	Al

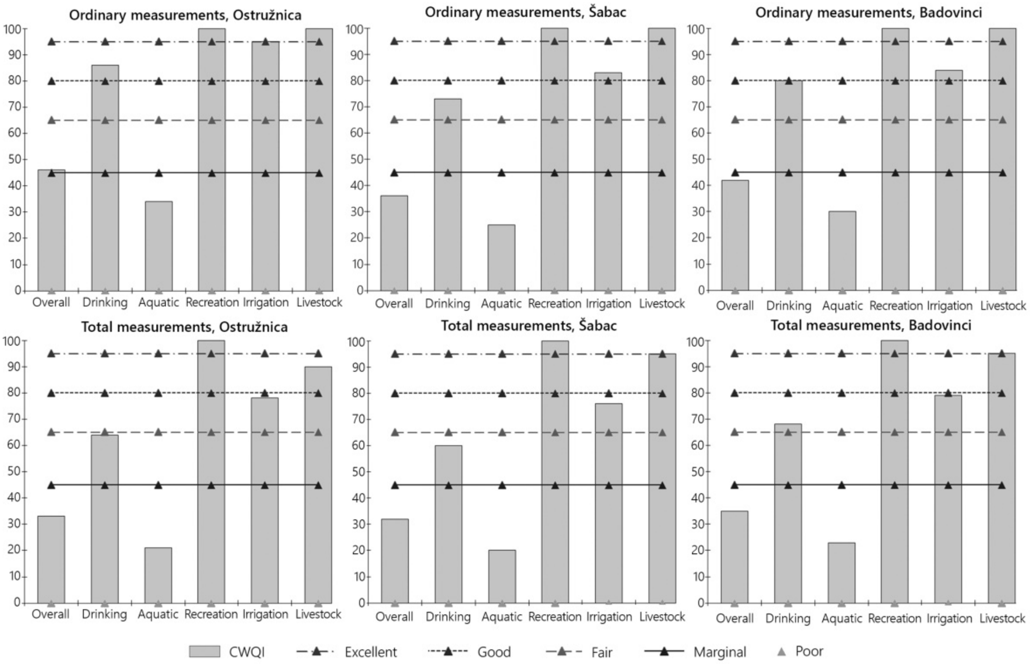


Figure 2. CWQI values.

A decline of water quality is also recorded for Šabac station in irrigation (from good to fair) and drinking (from fair to marginal). Less impairment is recorded in overall water quality (from 36 to 32), aquatic habitat (from 25 to 20), and livestock (from 100 to 95). Similar trend of water quality impairment was present in Badovinci station in irrigation (from good to fair) as well as in drinking (from fair to marginal), and less impairment in overall water quality (from 42 to 35), aquatic habitat (from 30 to 23) and livestock (from 100 to 95).

Water quality impairment was caused by extremely high values of many parameters during the flood. The most drastic example is Al value for Ostružnica station, which was 2890 times higher than the objective for overall and aquatic habitat. Al values (Figure 3) were also extremely higher than the objective for stations Šabac (2258 times) and Badovinci (1589 times).

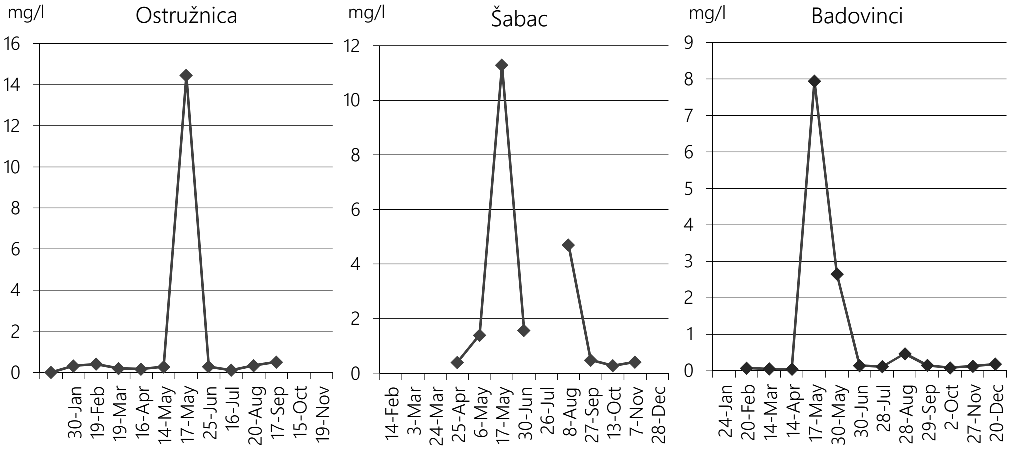


Figure 3. Al values for stations Ostružnica, Šabac, and Badovinci.

Heavy metals (micro elements) values were also significantly higher during the flood (Figure 4) in Ostružnica station: Pb value (58 times), Cr value (51 times), and Cu value (13 times), as well as in Badovinci station: Pb (61 times), Cr (13 times), and Cu values (9 times). Similar trends were recorded in Šabac station: Pb value (67 times) and Cu value (11 times).

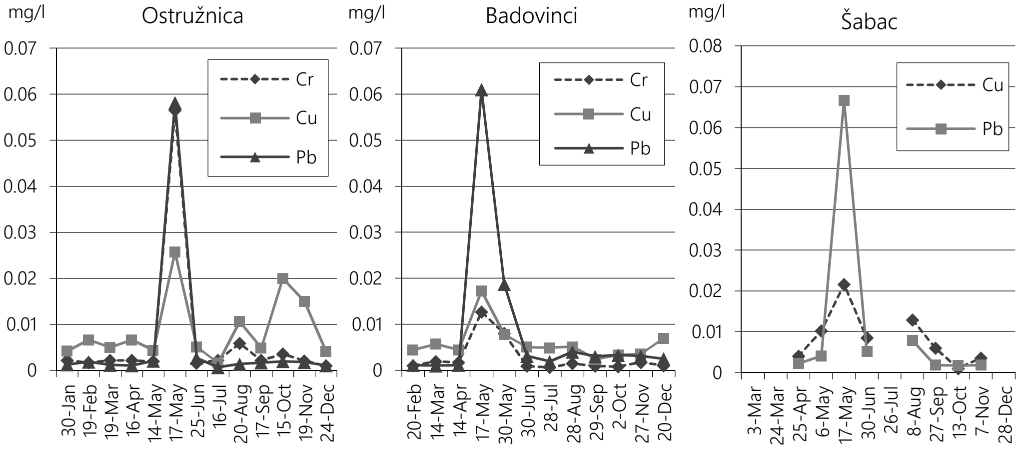
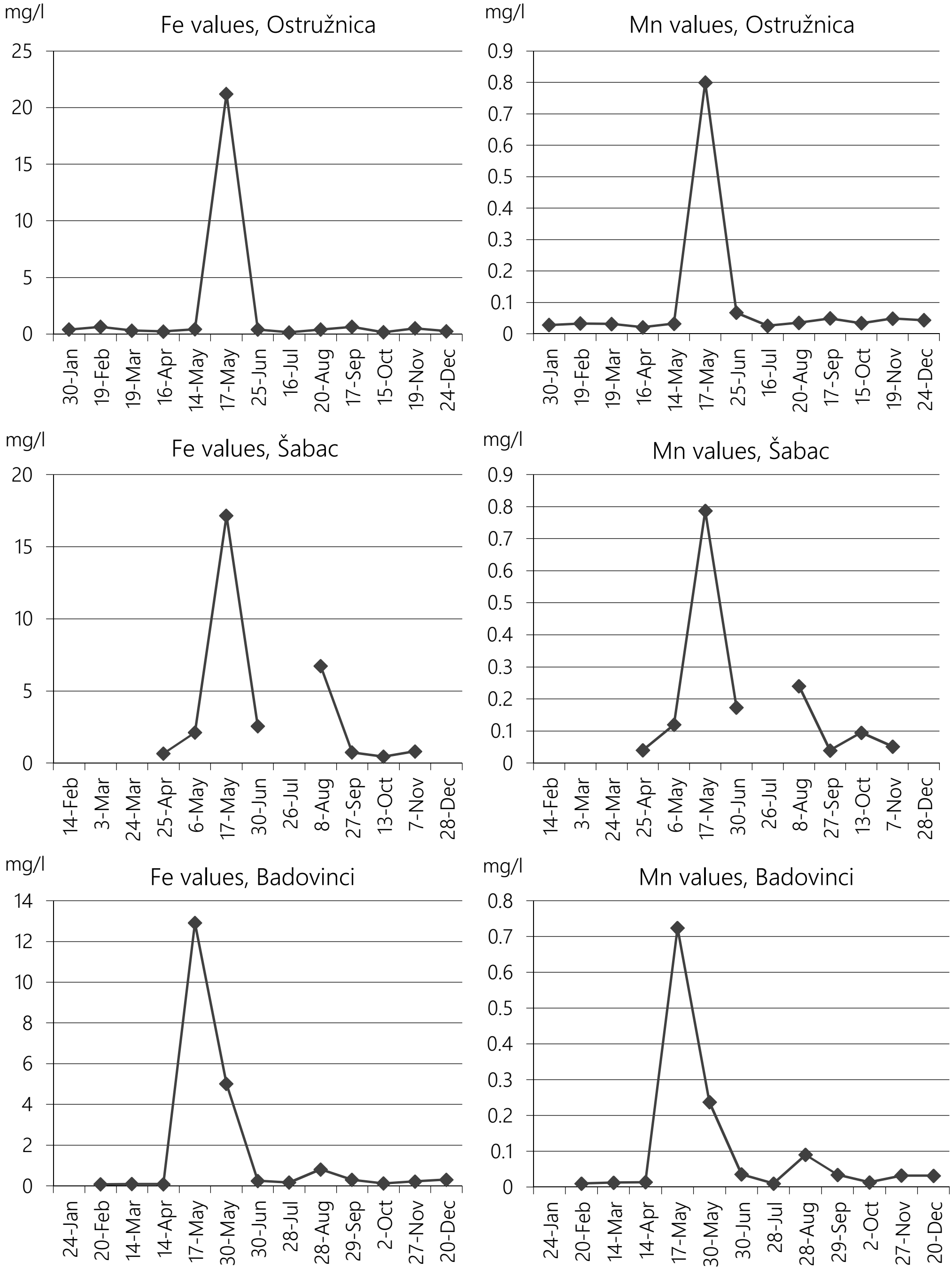


Figure 4. Micro-elements values for stations Ostružnica, Badovinci and Šabac.

Heavy metals (macro-elements) values were significantly higher during the flood (Figure 5) in Ostružnica station: Fe (71 times), Mn (16 times); in Šabac station: Fe (58 times), Mn (16 times), and in Badovinci station: Fe (43 times) and Mn (14 times).


Fe values, Ostružnica

Mn values, Ostružnica

Fe values, Šabac

Mn values, Šabac

Fe values, Badovinci

Mn values, Badovinci

Figure 5. Macro-elements values for stations Ostružnic, Šabac, and Badovinci.

Turbidity values (Figure 6) were also extremely higher than the objective during the flood: Ostružnica (74 times), Šabac (57.9 times), and Badovinci (53.1 times).

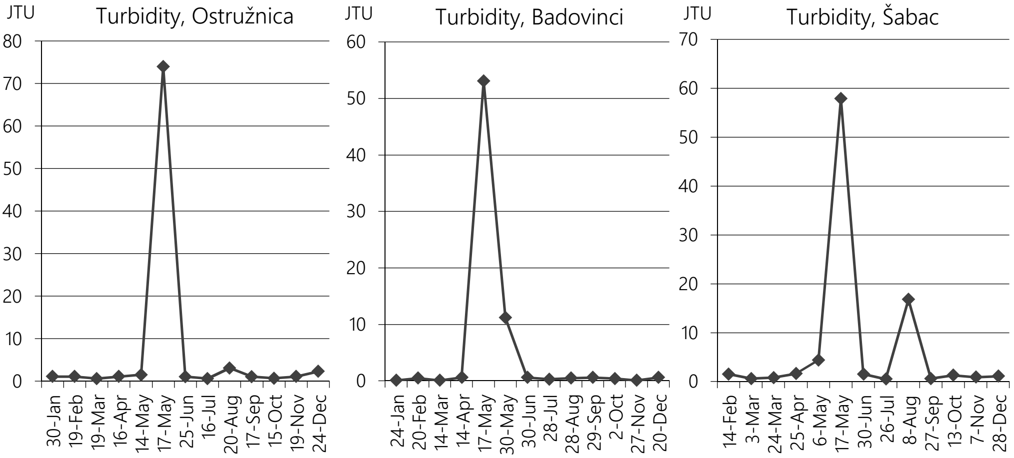


Figure 6. Turbidity values for stations Ostružnica, Šabac, and Badovinci.

During the flood, the values of As (in Ostružnica and Šabac stations) and Ni (in Ostružnica and Badovinci stations) were increased, while in all other measurements they were in normal ranges.

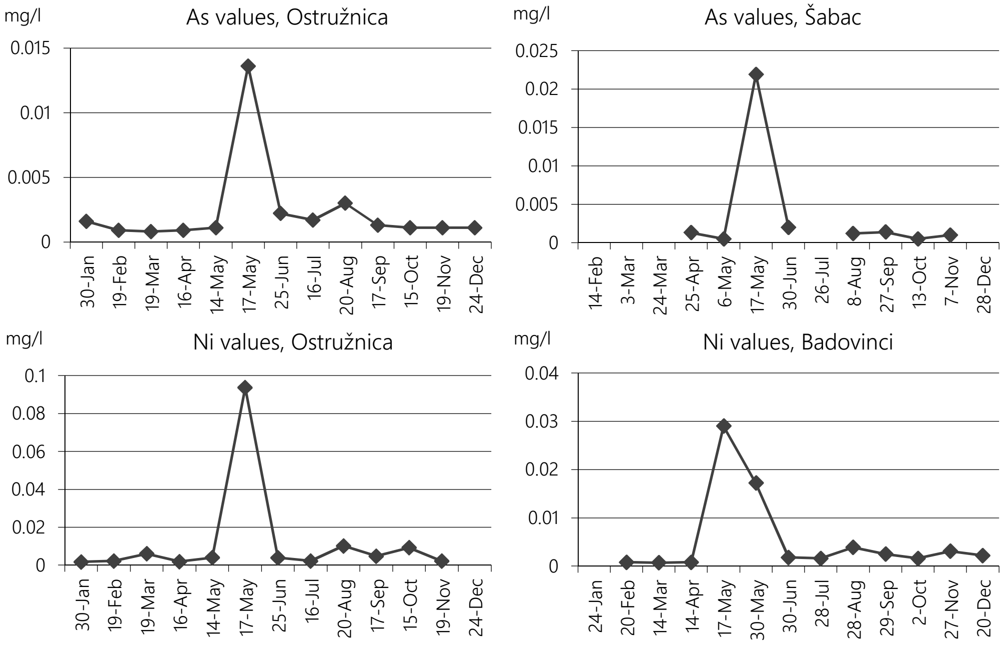


Figure 7. As and Ni values.

Besides the extraordinary measurement, the impact of flood on water quality was especially visible in the measurement from 30 May, 2014, immediately after the flood, in Badovinci station. The values of many parameters (Turbidity, Al, Cr, Fe, Mn, Ni, and Pb) were significantly higher than the objective and in comparison with other ordinary measurements.

Significant water quality decline, caused by the deviation of many parameters from normal ranges, cause many consequences in the environment. Heavy metal pollution may have harmful effects on the ecological balance of the recipient aquatic environment. It has particular significance in ecotoxicology because heavy metals are highly persistent and have the potential for bioaccumulation and implementation in food chain, and they become toxic to valuable fish species, wildlife resources and human beings (Damodharan, 2013; Davutluoglu, Seckin, Ersu, Yilmaz, & Sari, 2011). Turbidity may increase a possibility for waterborne diseases. Arsenic can cause severe toxicity through ingestion of contaminated water (Postolache, Girão, & Pereira, 2012). Aluminum has a toxic effect on the nervous system (Vasile et al., 2012).

Conclusion

Flood affected water quality in all the stations. Water quality decline was recorded in overall water quality as well as in water for specific uses: drinking, aquatic habitat, irrigation, and livestock. Many parameters (heavy metals and turbidity) showed tens of times higher values. The most drastic examples were Al values, which were thousands of times higher than the normal range. Due to the environmental consequences (including the harmful effects on aquatic species and human health), during the extreme events, such as floods, a network for water quality monitoring should be established. This is a way to prevent using contaminated water for different purposes. In order to achieve the most accurate results about water quality, the applied methodology could be used in combination with some other methodology for water quality assessment. More parameters and higher frequency of measurements would provide more results and imply trends in water quality changes. The establishment of a better monitoring system during floods and the implementation of the best available methodology for water quality assessment could contribute to the development of strategies and measures for water quality protection during extreme events. These measures could include nature-based solutions for water quality improvement and protections such as constructed wetlands and buffer zones which could mitigate flood ways and contribute to the enhancement of water quality.

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References

Aborgiba, M., Kostić, J., Kolarević, S., Kračun-Kolarević, M., Elbahi, S., Knežević-Vukčević, J., . . . Vuković-Gačić, B. (2016). Flooding modifies the genotoxic effects of pollution on a worm, a mussel and two fish species from the Sava River. *Science of the Total Environment*, *540*, 358–367. https://doi.org/10.1016/j.scitotenv.2015.03.120

Babić Mladenović, M. (Ed.). (2009). *Sub-Basin Level Flood Action Plan — Pannonian Southern Danube*. Vienna, Austria: International Commission for the Protection of the Danube River, Flood Protection Expert Group.

Baghapour, M. A., Nasseri, S., & Djahed, B. (2013). Evaluation of Shiraz wastewater treatment plant effluent quality for agricultural irrigation by Canadian Water Quality Index (CWQI). *Iranian Journal of Environmental Health Science and Engineering, 10,* 27. https://doi.org/10.1186/1735-2746-10-27

Blessing, N. R. W., & Benedict, S. (2017). Computing principles in formulating water quality informatics and indexing methods: An ample review. *Journal of Computational and Theoretical Nanoscience*, *14*(4), 1671–1681. https://doi.org/10.1166/jctn.2017.6531

Canadian Council of Ministers of the Environment. (2005). Canadian Water Quality Index 1.0 Calculator. Retrieved from http://www.env.gov.nl.ca/env/waterres/quality/background/cwqi.html#

Ciesielczuk, T., Kusza, G., Poluszyńska, J., & Kochanowska, K. (2014). Pollution of Flooded Arable Soils with Heavy Metals and Polycyclic Aromatic Hydrocarbons (PAHs). *Water, Air, & Soil Pollution, 225,* 2145. https://doi.org/10.1007/s11270-014-2145-0

Ciszewski, D., & Grygar, T. M. (2016). A Review of Flood-Related Storage and Remobilization of Heavy Metal Pollutants in River Systems. *Water, Air, & Soil Pollution, 227*, 239. https://doi.org/10.1007/s11270-016-2934-8

Damodharan, U. (2013). Bioaccumulation of Heavy Metals in Contaminated River Water-Uppanar, Cuddalore, South East Coast of India. In I. Ahmad & D. M. Ahmad (Eds.), *Perspectives in Water Pollution* (pp. 23–34). Rijeka, Croatia: InTech.

Dang, N. M., Babel, M. S., & Luong, H. T. (2011). Evaluation of flood risk parameters in the Day River Flood Diversion Area, Red River Delta, Vietnam. *Natural Hazards, 56*, 169–194. https://doi.org/10.1007/s11069-010-9558-x

Davutluoglu, O. I., Seckin, G., Ersu, C. B., Yilmaz, T., & Sari, B. (2011). Assessment of metal pollution in water and surface sediments of the Seyhan River, Turkey, using different indexes. *Clean—Soil Air Water*, *39*(2), 185–194. https://doi.org/10.1002/clen.201000266

Duan, W., He, B., Nover, D., Fan, J., Yang, G., Chen, W., Meng, H., & Liu, C. (2016). Floods and associated socioeconomic damages in China over the last century. *Natural Hazards*, *82,* 401–413. https://doi.org/10.1007/s11069-016-2207-2

Everett, G., Lamond, J. E., Morzillo, A. T., Matsler, A. M., & Chan F. K. S. (2018). Delivering Green Streets: an exploration of changing perceptions and behaviours over time around bioswales in Portland, Oregon. *Journal of Flood Risk Management, 11*(S2), 973–985. https://doi.org/10.1111/jfr3.12225

Gačić, J., Bošković, M., & Raković, J. (2013). Possibilities of the Republic of Serbia for Reducing Vulnerability to Natural Hazards. *Journal of the Geographical Institute "Jovan Cvijić" SASA*, *63*(3), 195–212. https://doi.org/10.2298/IJGI1303195G

Huang, J. J., & Xiang, W. (2015). Investigation of point source and non-point source pollution for Panjiakou Reservoir in North China by modelling approach. *Water Quality Research Journal, 50*(2), 167–181. https://doi.org/10.2166/wqrjc.2014.019

International Commission for the Protection of the Danube River. (2009). *Sub-Basin Level Flood Action Plan — Pannonian Central Danube*. Retrieved from https://www.icpdr.org/main/sites/default/files/6%20-%20Pannonian%20Central%20Danube%20FINAL.pdf

International Commission for the Protection of the Danube River & International Sava River Basin Commission. (2015). *Floods in May 2014 in the Sava River Basin — Brief overview of key events and lessons learned*. Retrieved from https://www.icpdr.org/main/sites/default/files/nodes/documents/sava_floods_report.pdf

Jakovljević, D. (2012). Serbian and Canadian Water Quality Index of Danube River in Serbia in 2010. *Journal of the Geographical Institute "Jovan Cvijić" SASA, 62*(3), 1–18. https://doi.org/10.2298/IJGI1203001J

Jakovljević, D., & Lozanov-Crvenković, Z. (2015). Water quality changes after Kraljevo earthquake in 2010. *Natural Hazards*, *79*, 2033–2053. https://doi.org/10.1007/s11069-015-1943-z

Krausmann, E., & Mushtaq, F. (2008). A qualitative Natech damage scale for the impact of floods on selected industrial facilities. *Natural Hazards*, *46*, 179–197. https://doi.org/10.1007/s11069-007-9203-5

Kuntiyawichai, K., Schultz, B., Uhlenbrook, S., Suryadi, F. X., & Van Griensven, A. (2011). Comparison of flood management options for the Yang River Basin, Thailand. *Irrigation and Drainage*, *60*(4), 526–543. https://doi.org/10.1002/ird.596

Marfai, M. A., Sekaranom, A. B., & Ward, P. (2015). Community responses and adaptation strategies toward flood hazard in Jakarta, Indonesia. *Natural Hazards*, *75*, 1127–1144. https://doi.org/10.1007/s11069-014-1365-3

Middelmann-Fernandes, M. H. (2010). Flood damage estimation beyond stage–damage functions: an Australian example. *Journal of Flood Risk Management, 3*(1), 88–96. https://doi.org/10.1111/j.1753-318X.2009.01058.x

Milanović Pešić, A., Jakovljević, D., & Milijašević Joksimović, D. (2020). Water Resources Management in Serbia. In A. Milanović Pešić & D. Jakovljević (Eds.), *Water Resources Management: Methods, Applications and Challenges* (pp. 231–299). New York, NY: Nova Science Publishers.

Milijašević Joksimović, D., Gavrilović, B., & Lović Obradović, S. (2018). Application of the Water Quality Index in the Timok River Basin (Serbia). *Journal of the Geographical Institute "Jovan Cvijić" SASA, 68*(3), 333–344. https://doi.org/10.2298/IJGI180610007M

Mladenović-Ranisavljević, I. I., & Žerajić, S. A. (2018). Comparison of different models of water quality index in the assessment of surface water quality. *International Journal of Environmental Science and Technology, 15,* 665–674. https://doi.org/10.1007/s13762-017-1426-8

Mogollón, B., Villamagna, A. M., Frimpong, E. A., & Angermeier, P. L. (2016). Mapping technological and biophysical capacities of watersheds to regulate floods. *Ecological Indicators*, *61*(2), 483–499. https://doi.org/10.1016/j.ecolind.2015.09.049

Mynett, A. E., & Vojinović, Z. (2009). Hydroinformatics in multi-colors—part red: urban flood and disaster management. *Journal of Hydroinformatics*, *11*(3–4), 166–180. https://doi.org/10.2166/hydro.2009.027

Postolache, O., Girão, P. S., & Pereira, J. M. D. (2012). Water Quality Monitoring and Associated Distributed Measurement Systems: An Overview. In K. Voudouris & D. Voutsa (Eds.), *Water Quality Monitoring and Assessment* (pp. 25–64). Rijeka, Croatia: InTech.

Radosavljevic, V., Belojevic, G., & Pavlovic, N. (2017). Tool for decision-making regarding general evacuation during a rapid river flood. *Public Health, 146*, 134–139. https://doi.org/10.1016/j.puhe.2017.01.025

Serbian Environmental Protection Agency. (2014). *Vanredno uzorkovanje reke Save na teritoriji grada Beograda i Šapca i reke Drine na teritoriji Badovinaca* [Report about extraordinary sampling of the Sava river on the territories of the cities Belgrade and Šabac and Drina river on the territory of Badovinci]. Belgrade, Serbia: Serbian Environmental Protection Agency.

Serbian Environmental Protection Agency. (2015). *Rezultati ispitivanja kvaliteta površinskih i podzemnih voda* [Results of the survey of surface water and groundwater quality]. Belgrade, Serbia: Serbian Environmental Protection Agency.

Shepherd, K. (2014). 2014: Record flooding in the Danube River Basin. *Danube Watch*, *2/2014*, 6–7. Retrieved from https://www.icpdr.org/main/publications/2014-record-flooding-danube-river-basin

Shesterkin, V. P. (2016). Variations of Amur water chemistry during the historical 2013 flood. *Water Resources, 43*(3), 495–503. https://doi.org/10.1134/S0097807816030155

Srivastava, G., & Kumar, P. (2013). Water Quality Index with missing parameters. *International Journal of Research in Engineering and Technology, 2*(4), 609–614. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=1CB56CEE9A903F091A1913D60B9A1BB1?doi=10.1.1.680.9161&rep=rep1&type=pdf

Su, J., Du, X., Li, X., Wang, X., Li, W., Zhang, W., . . . Zheng, B. (2016). Development and application of watershed scale indicator to quantify non-point sources P losses in semi-humid and semi-arid watershed, China. *Ecological Indicators, 63*, 374–385. https://doi.org/10.1016/j.ecolind.2015.12.002

Tsuzuki, Y. (2015). Relationships between pollutant discharge and water quality in the rivers from "better" to "worse" water quality. *Ecological Indicators, 52*, 256–269. https://doi.org/10.1016/j.ecolind.2014.12.001

Tunc Dede, O., Telci, I. T., & Aral, M. M. (2013). The Use of Water Quality Index Models for the Evaluation of Surface Water Quality: A Case Study for Kirmir Basin, Ankara, Turkey. *Water Quality, Exposure and Health*, *5,* 41–56. https://doi.org/10.1007/s12403-013-0085-3

Vasile, G., Cruceru, L., Dinu, C., Chiru, E., Gheorghe, D., & Ciupe, A. (2012). Evaluation of Drinking Water Quality in Three Municipalities in Romania: The Influence of Municipal and Customer's Distribution Systems Concerning Trace Metals. In K. Voudouris & D. Voutsa (Eds.), *Water Quality Monitoring and Assessment* (pp. 457–480). Rijeka, Croatia: InTech.

Venkatramanan, S., Chung, S. Y., Lee, S. Y., & Park, N. (2014). Assessment of river water quality via environmentric multivariate statistical tools and water quality index: a case study of Nakdong River Basin, Korea. *Carpathian Journal of Earth and Environmental Sciences*, *9*(2), 125–132. Retrieved from http://www.ubm.ro/sites/CJEES/viewTopic.php?topicId=426

Walker, D., Jakovljević, D., Savić, D., & Radovanović, M. (2015). Multi-criterion water quality analysis of the Danube River in Serbia: A visualisation approach. *Water Research, 79,* 158–172. http://dx.doi.org/10.1016/j.watres.2015.03.020

Zhang, C., Gao, X., Wang, L., & Chen, Y. (2013). Analysis of agricultural pollution by flood flow impact on water quality in a reservoir using a three-dimensional water quality model. *Journal of Hydroinformatics, 15*(4), 1061–1072. https://doi.org/10.2166/hydro.2012.131