ISSN 0354-8724 (hard copy) | ISSN 1820-7138 (online)

Correlation Between Discharge and Water Quality – Case Study Nišava River (Serbia)

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Received: November 19, 2017 | Revised: April 11, 2018 | Accepted: May 02, 2018

DOI: 10.5937/22-16674

Abstract

The water quality and river discharges were surveyed at two sites in Nišava River basin (Dimitrovgrad and Niš) with complete data series for the ten-year period (2005–2014). For these stations SWQI was calculated and correlation analysis was applied. The index value is dimensionless and varies between 0 and 100 (best quality) It is derived from numerous physical, chemical, biological and microbiological parameters. At Niš station average annual value of SWQI is 78 (good) with a clear decrease trend over a ten-year period. On the other side, on Dimitrovgrad station, average annual SWQI is 89 (very good) with a clear positive trend. Goal of this paper was to determine if there is a correlation between river discharge and values of SWQI. Results of the Pearson correlation test between SWQI and daily discharge values for Dimitrovgrad station show a moderate linear relation was observed, r= -0.287, p = 0.002. On Niš station same test has shown that there is no statistically significant relation between discharge and water quality (r=0.103 p= 0.297). This study has shown that the correlation between SWQI and discharge is weak or not present at all at the investigated river.

Keywords: Water Quality, Discharge, Nišava River, Serbia

Introduction

Identifying relationships between river water quality and discharge provides insight into understanding the river process chain. This is an important challenge because hydrological extremes (such are droughts and floods) are expected to become more commonplace in a changing climate (Kundzewicz et al., 2007). Aquatic ecosystems must be protected and managed to ensure that they retain their inherent vitality and remain fit for domestic, industrial, agricultural and recreational uses, for present as well for future generations. River systems worldwide are reported to be polluted due to untreated sewage disposal and industrial effluents being disposed directly or indirectly into the rivers. Wastes contain a wide variety of organic and inorganic pollutants. Serbian Water Quality Index (SWQI) was used for description of water quality. Results of several studies show that water quality, will be affected by streamflow volumes, both concentrations and total loads. Research conducted in Finland (Frisk et al., 1997; Kallio et al., 1997) indicates that changes in stream water quality, in terms of eutrophication and nutrient transport, are very dependent on changes in streamflow (Prathumratana et al., 2008). On the other hand, result of Eh Rak et al (2010) shows that pH, dissolved oxygen, conductivity and water temperature are not dependant on river discharge. As the SWQI is calculated based on the same parameters that were investigated in mentioned studies (Oxygen saturation, BOD, Ammonium, Ph value, Total oxidized nitrogen, Orthophosphates, Suspended solids, Temperature, Conductivity and Coliform bacteria). This study focused on finding relationship between river discharge and water quality parameters (SWQI) for Nišava River.

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Study area

The spring of Nišava River is located in Bulgaria, and the length of its course through Serbia is 195 km, and it is oriented SE-NW (Protić & Trajkovic, 2004). Its source is close to the Serbian border, on Bulgarian side of Stara Planina Mountain. It enters Serbia after 67 km of flow through Bulgarian territory without receiving any major tributaries. The river flows generally to the west for the remaining 151 km, it passes near cities of Dimitrovgrad, Pirot, Bela Palanka, and Niš after which the Nišava Rivers flows into the Južna Morava River. The river belongs to the Black Sea drainage basin. The surface area of the river basin is 3,74 km^2 in total, 3,641 km^2 belonging to Serbia (Branković & Trajković, 2007; Gocić & Trajković, 2013). The Nišava River is not navigable. It is the largest tributary of the Južna Morava, both in length and in discharge (36 m^3/s). The highest discharge occurs during the month of April - 55.14 m^3/s, while the lowest discharge occurs in September, 10.25 m3/s (Đokić, 2015). It has many tributaries, the biggest are Temštica from the right, and the Jerma, Crvena reka, Koritnička reka and Kutinska reka from the left.

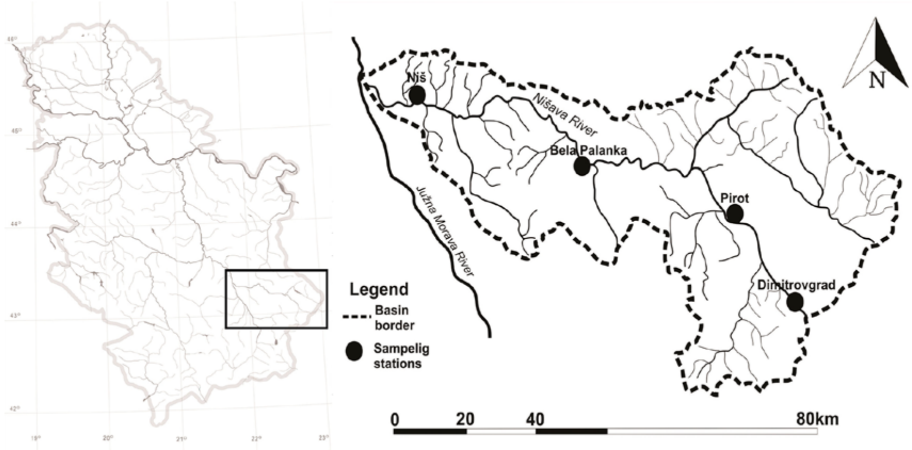

Figure 1. Map of the study area with stations with sufficient data

Methods and data

In this paper database of the Republic Hydrometeorological Service of Serbia for the 2005–2014 (Hydrological yearbook 2005-2014) period was used to present the existing state of water quality of Nišava River. Four kinds of parameters were measured at the two furthered stations on Nišava River: Dimitrovgrad and Niš during ten year period 2005–2014. Those parameters are physical, chemical, biological and microbiological and all are used in determining Water Quality Indices.

In Serbia, Serbian Water Quality Index (SWQI) is widely accepted index which is based on ten parameters (Oxygen saturation, BOD, Ammonium, Ph value, Total oxidized nitrogen, Orthophosphates, Suspended solids, Temperature, Conductivity and Coliform bacteria) and then their quality (q_i) represents features of surface water reducing them to one index number. Each parameter has different influence on general water quality, because of that, to each of them was assigned the weight (w_i) and the score of points according to their contribution to water quality endangering. The result ($q_i \cdot w_i$) gives the index 100, as an ideal summation of weights of all parameters (Oregon Water Quality Index Summary Report, 1996-2005). Index points, from 0 to 100, are assigned to particular waterbody according to the points assigned to particular parameters (Pantelić et al., 2012; Leščešen et al., 2014). Many studies show that SWQI method ensures general overview of surface water quality at certain place (Veljković, 2000; Veljković 2001; Đurašković & Vujović, 2004; Pantelić et al., 2012; Bjelajac et al., 2013; Leščešen et al., 2014).

Descriptive quality indicator has been determined for each SWQI values, ranging from excellent (90–100), very good (84–89), good (72–83), poor (39–71) and very poor (0–38). The limitation of SWQI is the relative small number of parameters that is used. For example, used parameters provide information about organic loading, but there is no information about heavy metal pollution. Since there is no single, universal parameter that properly describes surface water quality, investigators typically use several indicators related to sanitary quality, ability to sustain aquatic life, ecosystem productivity and aesthetics (Pharino, 2007; Bjelajac et al., 2013).

Correlation between SWQI and discharge data were estimated with Pearson Correlation Test. The Pearson Correlation Test was applied in order to establish the variables with significant differences. The correlation means the connection between variables while correlation coefficient means the measure based on which it can be concluded about the extent of their connection (Pantelić et al., 2015).

In case the value is equal to, or it makes approximately zero, the variables are independent from each other, but the opposite case is not always exclusively true (namely, if two variables are mutually dependent their correlation coefficient can be 0) because the correlation coefficient defines only the linear dependence between variables. The squared correlation coefficient (r^2), which is defined by an identical formula that is squared, is used in the analysis of linear dependence between two variables:

$$r_{xy}^2 = \frac{\sigma_{xy}^2}{\sigma_{xx}^2 \sigma_{yy}^2} = \frac{\left[\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})\right]^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}$$

In this case, the value of r^2 between two variables has to be positive in all cases (Wilks, 2006; Pantelić et al., 2015)

Results and discussion

After evaluating available data it was concluded that two stations have a satisfactory length of available data. SWQI was calculated 120 times throughout ten-year period for gauging station at Dimitrovgrad and average annual value of the index varies from 86 in 2006 to 90 in 2007, 2008, 2013 and 2014. These values, according to descriptive statistics vary from very good to excellent water quality. In Figure 2, (1a) it is clearly noticed a positive trend in SWQI values over ten year period (y=0.176x+87.93). For Niš station, same calculations for the same number of times were conducted and it has shown drastically different result.

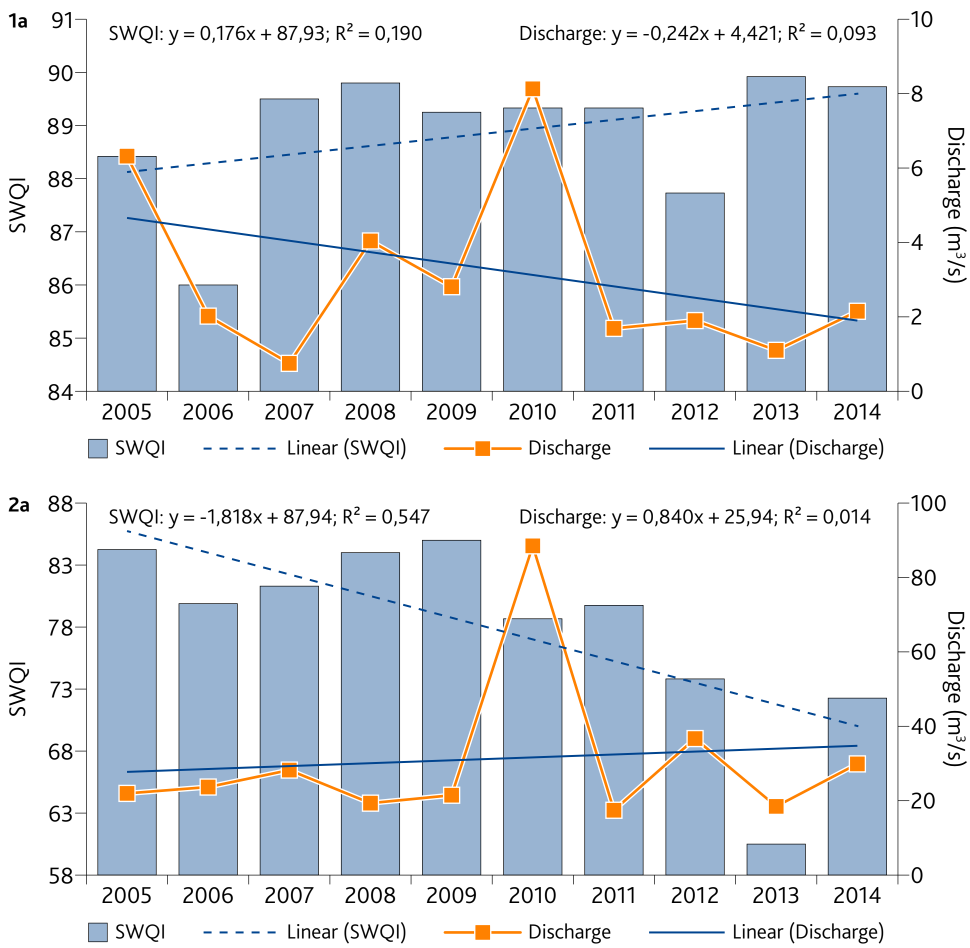

Figure 2. Average annual SWQI and discharge values at Dimitrovgrad (1a) and Niš (2a) stations

Lowes water quality was measured in 2013, 61 index points or descriptively poor water quality. The highest index was measured in 2009, 85 (very good). For this station, only two more times, in 2005 and 2008 index value was in the range of very good quality, both times index value was 84. In figure 2 (1b) a clear downward trend in water quality is noticed (y= -1.818x+87.94).

Annual average discharge values for Dimitrovgrad station vary from highest value in 2010 8.13 m³/s, with a negative trend y= -0.242x+4.421. On the other station, a moderate positive discharge trend over ten year period is noticed y= 0.840x+25.94.

The results of monthly values of SWQI and discharge values are presented in figure 3. While the SWQI on Dimitrovgrad station remains in very good-excellent range a negative trend is noticed y= -0.064x+89.33. On Niš station, monthly index values show the same range as the yearly index values, from poor till very good. As is the case with Dimitrovgrad station, Niš station shows negative trend y = -0.791x+82.58, starting from January till December. The reason for this situation at Niš station is that the biggest polluters of the Nišava river water are waste waters from the sewages of the settlements along the river, upriver from the city of Niš. Industrial waste waters, for the time being, do not represent a big threat for the river. However, future increase of the industrial production may cause further deterioration of water quality. Monthly discharge values show the same trend as water quality indexes.

Figure 3 shows that discharge of Nišava River is highest during April and lowest August and September. On the other side, SWQI values are highest during January and lowest during April (Dimitrovgrad station) and October (Niš station). The trend lines are showing that both discharge and SWQI are declining from January till December. The monthly analysis of SWQI shows that during summer months (Jun, July and August) the values of SWQI are the lowest on both stations. At Dimitrovgrad station negative trend for the months of June (y = -0,630x + 90,66) and July (y = -0,084x + 88,26) are observed while during August a positive trend is observed (y = 0,139x + 87,73). A negative trend is clearly visible during summer months over ten-year period at Niš station, Jun (y = -0,387x + 75,33) July (y = -2,375x + 88,66) and August (-3,883x + 91,63).

Results of Pearson correlation test between SWQI and daily discharge values for Dimitrovgrad station show a moderate linear relation was observed, r=

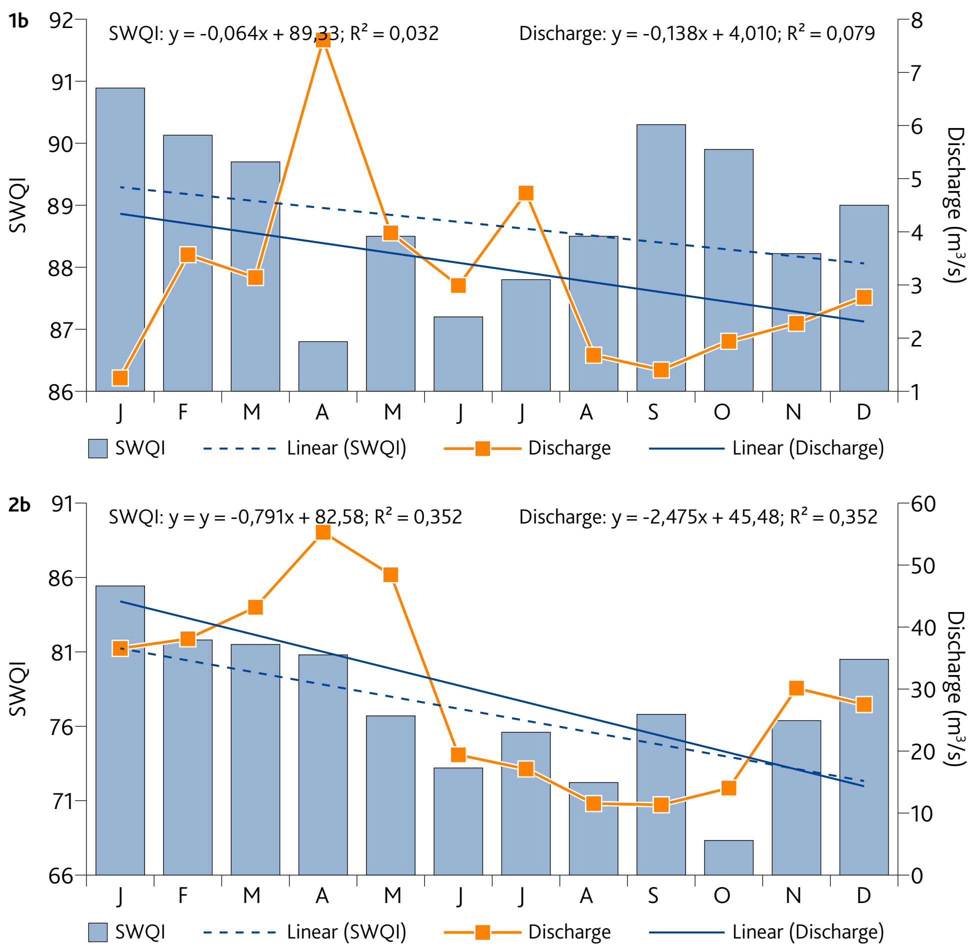

Figure 3. Average monthly SWQI and discharge values at Dimitrovgrad (1b) and Niš (2b) stations

-0.287, p = 0.002 (2-sided). On Niš station same test has shown that there is no statistically significant relation between discharge and water quality (r=0.103 p= 0.297).

The results of correlation tests show that there is weak statistically significant correlation between discharge and SWQI parameters at Dimitrovgrad station. We can conclude that water discharge will not influence the concentrations of ten parameters that are crucial in estimating SWQI at Niš station. The similar conclusion is given by Eh Rak et al. (2010) in their study of Endau Catchment in Malaysa. On the other side, low discharge values show statistically significant correlation between discharge and SWQI. Results of Prathumratana et al (2008), also show that Dissolved oxygen and Total suspended solids had weak correlations with the discharges of Mekong River. Negative relationship between the values of all water quality variables (except water temperature, and pH) and discharge were observed in Yeşilırmak River in Turkey. That is, as discharge increased the values and concentration of these variables decreased (Kurnuc et al., 2005). WQI of Subernarekha River in India shows that values at various sampling stations generally progressively decline in WQI values along the river, this is also the case with Nišava River. Thus, a general progressive decline in WQI values along the downstream parts of river indicated an increase in pollution due to the discharge by various industries along the stretch (Parmar et al., 2010). According to the recorded values of WQI of Qualyasan stream in Iraq, the studied sampling sites, show a decreasing trend in WQI values with increasing of discharge downstream (Khwakaram et al., 2015).

Projections of future show that climate change will affect hydrologic and thermal regimes of rivers, having a direct impact on freshwater ecosystems and human water use (Schneider et al., 2013). Projections of water quality in the future indicate further deterioration of water quality in southeastern United States, Europe, eastern China, southern Africa and southern Australia. These regions could potentially be affected by increased deterioration of water quality and freshwater habitats, and reduced water available for human uses such as thermoelectric power and drinking water production (van Villet et al., 2013). Our preliminary research has shown that the models that project changes of water quality based on discharge changes do not work on Nišava River because the correlation between discharge and water quality parameters are very week or non existing. On water quality of Nišava River is under stronger influence by waste water from settlements then under discharge changes during years.

Conclusion

Overall average water quality index was 83 which indicate good quality of water in the Nišava River. The water quality index reduced towards the downstream of the river. Sampling sites under investigation fell under the very good quality index (Dimitrovgrad 89), with Niš station exhibiting the lowest index values 78 (good quality). Water quality deteriorated, as river flows downstream towards river confluence into Južna Morava River. Impact of river discharge on water quality parameters is statistically significant at Dimitrovgrad station, where lower discharge values are measured. Downstream parts of the river, where discharge values increases the impact of discharge to water quality parameters decreases.

On the basis of the analyzed data and presented results, in order to provide an appropriate long-term water quality of the river Nišava, it is crucial to take certain steps which would provide a sustainable water management. Sustainable management of the water quality of Nišava River should lead toward improving the quality of life of the entire population of the region and improvement of the environmental conditions in all settlements along this river. Furthermore, these results can be helpful for planning and controlling the water quality of the Nišava River as this river is the most important natural resources of the third largest Serbian city (Niš) but the sustainable development and improvement of river water quality is not possible without the wider regional approach.

As a conclusion, it can be clearly stated that it is important to understand the relationship between water quality and river discharge and their effect. Water quality monitoring is importance due to threat such activities are harmful to aquatic organisms and public health. Furthermore, discharging of industrial and domestic wastewater and also other anthropogenic activities were the main sources for contaminating Nišava River. Also, there should be regular and continuous monitoring for water quality of the river in order to detect changes in physiochemical parameters of the river water at different sites. The results presented here provide a baseline reference on the future monitoring of the Nišava River basin.

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