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Prediction of Delivered Quantities of Drinking Water and Discharged Wastewater of the Nišava District (Serbia)

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Abstract

Water, as a natural resource, is the most basic substance of life that has immeasurable significance for the living world, ecosystems, and planet earth. In this paper, a prediction of delivered quantities of drinking water (DQDW) and total discharged wastewater (TDWW) of the Nišava district (Serbia) for the period 2019-2023 is given. The prediction for DQDW for the period 2019-2023 was made based on linear regression model, quadratic regression model, and cubic regression model according to which the data on DQDW of the Nišava district (Serbia) for the period 2006-2018 were approximated. The prediction for TDWW for the period 2019–2023 was done based on the 4th-degree polynomial regression model, the 5th-degree polynomial regression model, and the 6th-degree polynomial regression model by which the DQDW data were approximated of the Nišava district (Serbia) for the period 2006–2018. The presented prediction is a continuation of the paper “Trend analysis of total affected water and total discharged wastewater of the Nišava district (Serbia)” by the same author, in which for data on DQDW and TDWW of the Nišava district (Serbia) for the period 2006–2018 trend analysis and selected regression models have been shown.

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Introduction

Natural resources (NR) are raw organic materials or substances, found in nature and representing the general natural wealth with its usable value for industrial production and/or consumption [1], [2], [3], [4], [5]. Statistical analysis of different NR is given in papers [6], [7], [8], [9].

One of the main factors of NRs is water, which is a non-organic material. Water is consumed by plants, animals, and humans.

The most essential material and a natural resource, water, are unambiguously significant for the life and the living world, ecosystems, and planet Earth. The significance of water is maintaining and enabling life by constantly circulating in nature between the earth and the atmosphere. Water is spectacular in its moving, changing its appearance and never really disappearing. It has been present on earth for hundreds of millions of years, consumed by plants, animals, and humans.

Water quality index (WQI) assesses the most important characteristic of water its quality. The analysis of WQI in different regional territories is presented in the following papers [10], [11], [12], [13], [14], [15], WQI as management tool is given in paper [16], and as classification tool it is given in papers [17], [18]. Prediction of WQI is given in papers [19], [20], [21], etc.

In this paper, a prediction of delivered quantities of drinking water (DQDW) and total discharged wastewater (TDWW) of Nišava district (Serbia) for the period 2019-2023 is given.

Data and Methods

Data on values of DQDW and TDWW of Nišava district (Serbia) are taken from “Municipalities and Regions in the Republic of Serbia” of the Statistical Office of the Republic of Serbia for the period 2006–2018 [22], [23], [24], [25], [26], with significant calculations by the authors.

Niš, Aleksinac, Gadžin Han, Doljevac, Merošina, Ražanj and Svrljig are the municipalities of the Nišava District (Figure 1). In 2018, the total area for the Nišava district was 2728 km^2. Population in Nišava district was 381.757 (187.780 and 193.977, men and women, respectively) in 2002 and in 2018 it was 362.331 [26], which is less for 19.426 or CAGR=-0.33% and CGI=94.91% [1].

Figure 1: Map of the Nišava district

For the prediction of DQDW and total discharged waste-water (TDWW) of Nišava district (Serbia) for the period 2019–2023, polynomial regression models (PRM) are used. The estimation of parameters of the PRM models was realized using the least-squares method (LSM), and software (MS-Excel) using the LSM method was used [27], [28], [29]. Examples of determination of PRM models are described in the papers [27], [30], [31], [32], etc.

Standard statistical analysis methods and MS-Excel software system were used to calculate the statistical description parameters, graphical representation of data, approximation, and prediction of the DQDW and total discharged waste-water (TDWW) for Nišava district (Serbia) [27], [28], [29].

Results and Discussion

In Table 1, data are given about total affected quantities of water (TAQW), DQDW, and total discharged waste-water (TDWW) for Nišava district (Serbia) for the period 2006-2018 [1], [22], [22], [23], [24], [25], [26].

The data about TAQW [$\times 10^3$ m³] for Nišava district (Serbia) for the period 2006-2018 changed in intervals from 5783-41740, with arithmetic mean AM=25771.85, and the median are Med=37782. Standard deviation is SD=15831.5 and coefficient of variation is CoV=61.43. Values of trend analysis are the following: CGI=23.79% in 2018 compared to 2006, and CAGR=–8.58% per year for the period 2006–2018 [1].

Table 1: Data on water supply for Nišava district for the period 2006–2018

Year	Total affected quantities of water ($\times 10^3$ m³)	Delivered quantities of drinking water ($\times 10^3$ m³)	Total discharged wastewater ($\times 10^3$ m³)
2006	41,740	23,777	19,097
2007	40,536	25,418	18,940
2008	38,965	24,214	17,967
2009	37,782	22,982	15,964
2010	38,045	23,099	16,820
2011	40,051	22,918	16,287
2012	41,314	23,030	22,393
2013	8871	23,018	22,374
2014	5783	19,805	19,411
2015	10,378	23,306	22,669
2016	10,726	21,775	21,247
2017	10,912	21,180	20,651
2018	9931	20,402	19,897

The data about DQDW ($\times 10^3$ m³)s for Nišava district (Serbia) for the period 2006–2018 changed in intervals from 19805 to 25418, with AM=22686.46, and Med=23018. Standard deviation is SD=1541.88 and CoV=6.80. Values of trend analysis are: CGI=85.81% in 2018 compared to 2006, and CAGR=–0.95% per year for the period 2006–2018 [1].

For prediction of DQDW for Nišava district (Serbia) for the period 2019-2023, data about DQDW for the period 2006-2018 are approximated using linear regression model (LRM), quadratic regression model (QRM), and cubic regression model (CRM).

Equation of LRM for approximation of the data about DQDW for Nišava district (Serbia) for the period 2006-2018 is presented in the following form:

$$DQDW = 649634.51 - 311.60\ y \quad (1)$$

with coefficient of correlation R=0.7870 and coefficient of determination R^2=0.6194.

Where: *y* – year and *DQDW* – Delivered quantities of drinking water ($\times 10^3$ m³).

Equation of QRM for data approximation about DQDW for Nišava district (Serbia) for the period 2006-2018 is presented in the following form:

$$DQDW = -6.57715\ 10^6 + 6872.1\ y - 1.7852\ y^2 \quad (2)$$

with coefficients R=0.7872 and R^2=0.6197.

Equation of CRM for approximation of the data about *DQDW* for Nišava district (Serbia) for the period 2006–2018 is presented in the form:

$$DQDW = 5.74842\ 10^9 - 8.57417\ 10^6\ y + 4263.157\ y^2 - 0.70658\ y^3 \quad (3)$$

with coefficients R=0.7874 and R^2=0.6200.

Table 2 shows LRM, QRM, and CRM regression models for DQDW for Nišava district for the period 2006–2018, with values for coefficients R and R^2.

Table 2: Regression models for delivered quantities of drinking water (DQDW) in (×103 m³) for Nišava district for the period 2006–2018

No.	Model	Form of regression equation	R	R^2
1.	Linear regression model	DQDW=649634.51–311.60.y	–0.7870	0.6194
2.	Quadratic regression model	DQDW=–6.577147.10^6+6872.1.y–1.7852.y^2	0.7872	0.6197
3.	Cubic regression model	DQDW=5.74842.10^9–8.57417.10^6.y+4263.157.y^2–0.70658.y^3	0.7874	0.6200

From Table 2, it can be seen that all three analyzed regression models (LRM, QRM, and CRM) describe approximately the same statistical data for DQDW for Nišava district (Serbia) for the period 2006-2018, because their coefficients R and R_2 are approximately equal.

Table 3: Statistical and calculated values for DQDW for LRM, QRM, and CRM models for Nišava district for the period 2006–2018

Year	DQDW ($\times 10^3$ m³)	Calculated values for DQDW		
		for LRM	for QRM	for CRM
2006	23,777	24,556.09	24,516.81	24,563.45
2007	25,418	24,244.48	24,224.85	24,224.85
2008	24,214	23,932.88	23,929.31	23,903.87
2009	22,982	23,621.27	23,630.20	23,596.28
2010	23,099	23,309.67	23,327.52	23,297.85
2011	22,918	22,998.07	23,021.27	23,004.32
2012	23,030	22,686.46	22,711.45	22,711.45
2013	23,018	22,374.86	22,398.06	22,415.02
2014	19,805	22,063.25	22,081.10	22,110.78
2015	23,306	21,751.65	21,760.57	21,794.49
2016	21,775	21,440.04	21,436.47	21,461.91
2017	21,180	21,128.44	21,108.80	21,108.80
2018	20,402	20,816.84	20,777.56	20,730.93

Statistical and calculated values for DQDW for LRM, QRM, and CRM models for Nišava district for the period 2006-2018 are shown in Table 3 and prediction values for DQDW for LRM, QRM, and CRM models for Nišava district for the period 2020-2024 in Table 4.

Table 4: Prediction values for DQDW for LRM, QRM, and CRM models for Nišava district for the period 2020–2024

Year	Prediction values for DQDW		
	for LRM	for QRM	for CRM
2019	20,505	20,437	20,387
2020	20,194	20,098	19,957
2021	19,882	19,755	19,489
2022	19,571	19,409	18,981
2023	19,259	19,059	18,428

Figures 2-4 show the statistical values for DQDW of Nišava district (Serbia) for the period 2006–2018 and the curves for LRM, QRM, and CRM, retrospectively, with prediction values (blue curve in figures) for the period 2019–2023.

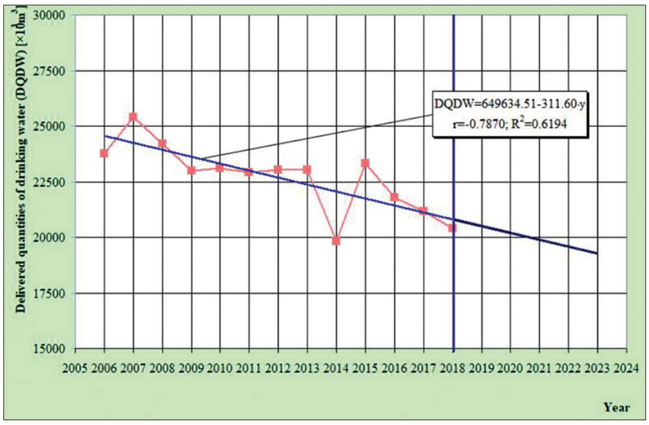

Figure 2: Approximated delivered quantities of drinking water for Nišava district (Serbia) for the period 2006–2018 using linear regression model with prediction values for the period 2019–2023

The data about TDWW ($\times 10^3$ m³) for Nišava district (Serbia) for the period 2006–2018 changed in intervals from 15964 to 22669, with AM=19516.69, and Med=19411. Standard deviation is SD=2310.23 and CoV=11.84. Values of trend analysis are: CGI=104.19% in 2018 compared to 2006, and CAGR=0.26% per year for the period 2006–2018 [1].

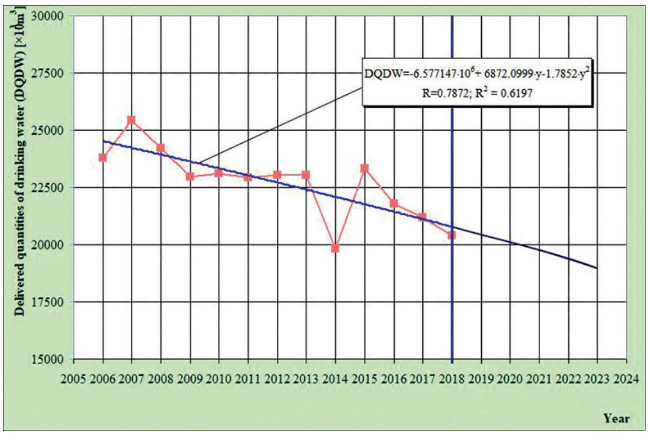

Figure 3: Approximated delivered quantities of drinking water for Nišava district (Serbia) for the period 2006–2018 using quadratic regression model with prediction values for the period 2019–2023

For prediction of TDWW for Nišava district (Serbia) for the period 2019–2023, data about TDWW for the period 2006-2018 are approximated using 4th-degree polynomial regression model (PRM4), 5th-degree polynomial regression model (PRM5), and 6th-degree polynomial regression model (PRM6).

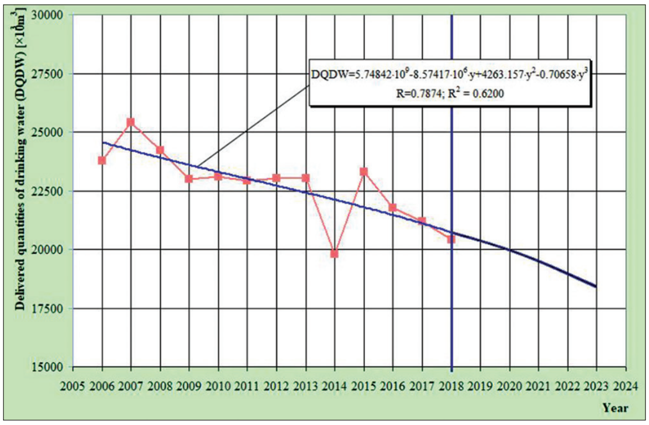

Figure 4: Approximated delivered quantities of drinking water for Nišava district (Serbia) for the period 2006–2018 using cubic regression model with prediction values for the period 2019–2023

Equation of PRM4 for approximation of the data about TDWW for Nišava district (Serbia) for the period 2006-2018 is presented as follows:

$$TDWW = 2139.4084443.10^5 - 42406941511.776.y + 31521507.6319.y^2 - 10413.33863.y^3 + 1.29003.y^4 \quad (4)$$

with coefficients R=0.7778 and R^2=0.6049.

Where: *y* – year and *TDWW* – Total discharged waste-water ($\times 10^3$ m³).

Equation of PRM5 for approximation the data about TDWW for Nišava district (Serbia) for the period 2006-2018 is presented in the following form:

$$TDWW = 5124997.631647.10^{10} + 127372101954392.y - 126623482277.547.y^2 + 62939529.68857.y^3 - 15642.35137.y^4 + 1.55503.y^5 \quad (5)$$

Table 5: Regression models for total discharged wastewater (×10³ m³) for Nišava district for the period 2006–2018

No.	Model	Form of regression equation	R	R^2
1.	PRM4	$TDWW=2139.40844429234.10^5–42406941511.7762.y+31521507.6319.y^2–10413.33863.y^3+1.29003.y^4$	0.7778	0.6049
2.	PRM5	$TDWW=5124997.631647.10^{10}+127372101954392.y–126623482277.547.y^2+62939529.68857.y^3–15642.35137.y^4+1.55503.y^5$	0.8207	0.6736
3.	PRM6	$TDWW=–30938.78884488.10^{15}+92.237739224.10^{15}.y–11457.828268862.10^{10}.y^2+75909172177.8344.y^3–28288393.7586.y^4+5622.3854.y^5–0.4656.y^6$	0.8515	0.7251

with coefficients R=0.8207 and R^2=0.6736.

Equation of PRM6 for approximation of the data about TDWW for Nišava district (Serbia) for the period 2006–2018 is presented in form:

$$TDWW=–30938.78884488\ 10^5+92.237739224\ 10^{15}\ y–11457828268862\ 10^{10}\ y^2+75909172177.8344\ y^3–28288393.7586\ y^4+5622.3854\ y^5–0.4656\ y^6 \quad (6)$$

with coefficients R=0.8515 and R^2=0.7251.

Table 5 shows PRM4, PRM5, and PRM6 regression models for TDWW for Nišava district for the period 2006–2018, with values for coefficients R and R^2.

From Table 5, it can be seen that the PRM6 best describes the statistics for DQDW for Nišava district (Serbia) for the period 2006-2018, because its coefficients R and R^2 are the highest.

Statistical and calculated values for TDWW for PRM4, PRM5, and PRM6 models for Nišava district for the period 2006–2018 are shown in Table 6.

Table 6: Statistical and calculated values for TDWW for PRM4, PRM5, and PRM6 models for Nišava district for the period 2006–2018

Year	TDWW (×10³ m³)	Calculated values for TDWW		
		For PRM4	For PRM5	For PRM6
2006	19,097	19,888.32	19,608	19,708
2007	18,940	17,782.42	18,848	18,918
2008	17,967	16,910.57	17,424	17,498
2009	15,964	16,946.41	16,744	16,734
2010	16,820	17,594.53	17,008	17,003
2011	16,287	18,590.50	18,168	18,238
2012	22,393	19,700.78	19,808	19,914
2013	22,374	20,722.87	21,400	21,432
2014	19,411	21,485.15	22,304	22,296
2015	22,669	21,846.97	22,288	22,277
2016	21,247	21,698.69	21,304	21,310
2017	20,651	20,961.51	20,128	20,211
2018	19,897	19,587.71	20,248	20,202

Figures 5-7 show the statistical values for TDWW (×10³ m³) of Nišava district (Serbia) for the period 2006-2018 and the curves for PRM4, PRM5, and PRM6, retrospectively, with prediction values (blue curve in figures) for the period 2020–2024.

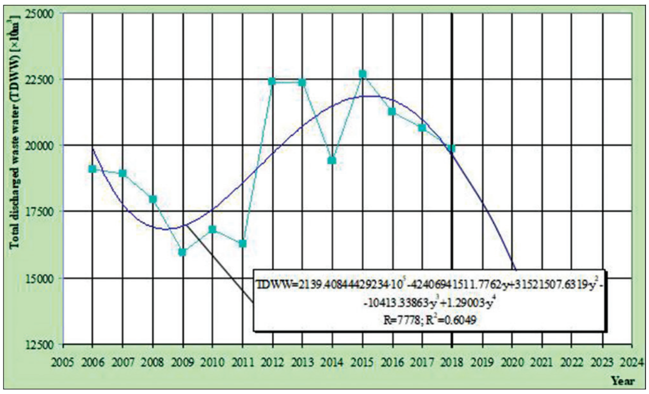

Figure 5: Approximated total discharged wastewater for Nišava district (Serbia) for the period 2006–2018 using 4th-degree polynomial regression model with prediction values for the period 2019–2023

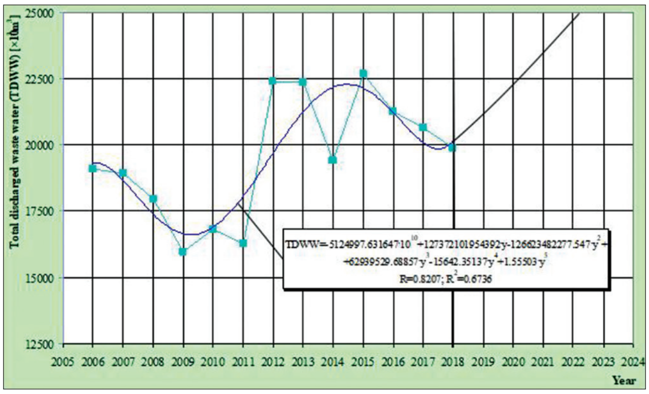

Figure 6: Approximated total discharged wastewater for Nišava district (Serbia) for the period 2006–2018 using 5th-degree polynomial regression modelwith prediction values for the period 2019–2023

Based on polynomial regression models (PRM): RPM4 (Figure 5), PRM5 (Figure 6), and PRM6 (Figure 7) predictions for TDWW differ greatly so that for PRM4 and PRM6 models are predicted a decrease values of TDWW for the period 2019-2013 (Figures 5 and 7, respectively) and the PRM5 model predicts an increase values or growth of TDWW (Figure 6).

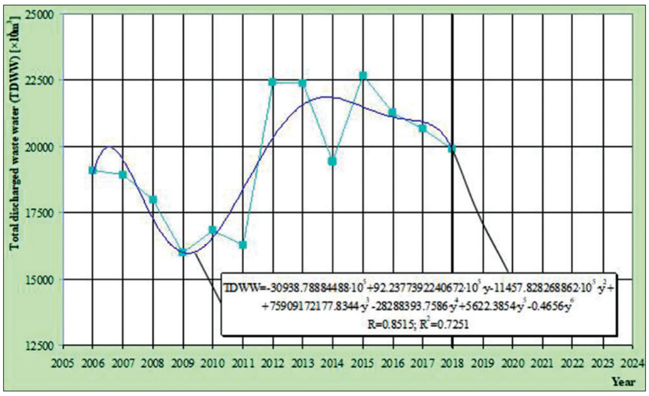

Figure 7: Approximated total discharged wastewater for Nišava district (Serbia) for the period 2006–2018 using 6th-degree polynomial regression model with prediction values for the period 2019–2023

Conclusion

Values for DQDW (×10³ m³) for Nišava district (Serbia) for the period 2006–2018 decreased from 23,777 in 2006 to 20,402 in 2018 (CGI=85.81% in 2018 compared to 2006, and CAGR=–0.95% per year) [1].

The prediction for DQDW for Nišava district (Serbia) for the period 2019-2023 was made based on LRM, QRM, and CRM models. Values for DQDW for Nišava district (Serbia) for the period 2006–2018 is approximated using: LRM model (eq. 1) with coefficients r=–0.7870 and R^2=0.6194, QRM model (eq. 2) with coefficients R=0.7872 and R^2=0.6197 and CRM model (eq. 3) with coefficients R=0.7874 and R^2=0.6200. Since for all three models (LRM, QRM, and CRM), the coefficients R and R^2 are approximately equal, for DQDW prediction it can be realized on the basis of any of the mentioned three models.

Values for TDWW (×10^3 m³) for Nišava district (Serbia) for the period 2006–2018 increased from 19097 in 2006 to 19897 in 2018 (CGI=104.19% in 2018 compared to 2006, and CAGR=0.26% per year).

The prediction for TDWW for Nišava district (Serbia) for the period 2019-2023 was done based on the PRM4, PRM5, and PRM6 models. Values for TDWW for Nišava district (Serbia) for the period 2006-2018 are approximated using: PRM4 model (eq. 4), with coefficients R=0.7778 and R^2=0.6049, PRM5 model (eq. 5), with coefficients R=0.8207 and R^2=0.6736 and PRM6 model (eq. 6), with coefficients R=0.8515 and R^2=0.7251. Since the coefficients R and R^2 are the highest for the PRM6 model, this model can be adopted as the most adequate for predicting TDWW.

Based on the TDWW analysis, it can be concluded that the prediction values differ greatly from the chosen polynomial regression model (PRM4, PRM5, or PRM6).

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