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.

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 km². 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].
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 ($\times10^3$ m$^3$) for Nišava district (Serbia) for the period 2006–2018 changed in intervals from 5783 to 41740, with arithmetic mean AM=25771.85, and the median are Med=37782. 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:

\[ DQDW = 649634.51 - 311.60 \times y \] (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 ($\times10^3$ m$^3$).

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

\[ DQDW = -6.57715 \times 10^6 + 6872.1 \times y - 1.7852 \times y^2 \] (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:

\[ DQDW = 5.74842 \times 10^6 - 8.57417 \times 10^6 \times y + 4263.157 \times y^2 - 0.70658 \times y^3 \] (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 1: Data on water supply for Nišava district for the period 2006–2018

| Year | Total affected quantities of water ($\times10^3$ m$^3$) | Delivered quantities of drinking water ($\times10^3$ m$^3$) | Total discharged wastewater ($\times10^3$ m$^3$) |
|------|----------------------------------------------------|--------------------------------------------------------|---------------------------------------------|
| 2006 | 41,740                                             | 23,777                                                 | 19,097                                      |
| 2007 | 40,536                                             | 25,418                                                 | 18,940                                      |
| 2008 | 38,965                                             | 24,214                                                 | 17,967                                      |
| 2009 | 37,782                                             | 22,962                                                 | 15,964                                      |
| 2010 | 38,045                                             | 23,099                                                 | 16,820                                      |
| 2011 | 40,051                                             | 22,918                                                 | 16,287                                      |
| 2012 | 41,314                                             | 23,030                                                 | 22,395                                      |
| 2013 | 8871                                               | 23,018                                                 | 22,374                                      |
| 2014 | 5783                                               | 19,085                                                 | 19,411                                      |
| 2015 | 10,378                                             | 19,111                                                 | 20,651                                      |
| 2016 | 10,726                                             | 23,306                                                 | 22,982                                      |
| 2017 | 10,912                                             | 21,180                                                 | 23,099                                      |
| 2018 | 9531                                               | 20,402                                                 | 23,018                                      |

Table 2: Regression models for delivered quantities of drinking water (DQDW) in ($\times10^3$ m$^3$) for Nišava district for the period 2006–2018

| No. | Model | Form of regression equation | R  | R²  |
|-----|-------|-----------------------------|----|-----|
| 1.  | Linear regression model | $DQDW=649634.51 - 311.60 \times y$ | -0.7870 | 0.6194 |
| 2.  | Quadratic regression model | $DQDW=-6.57715 \times 10^6 + 6872.1 \times y - 1.7852 \times y^2$ | 0.7872 | 0.6197 |
| 3.  | Cubic regression model | $DQDW=5.74842 \times 10^6 - 8.57417 \times 10^6 \times y + 4263.157 \times y^2 - 0.70658 \times y^3$ | 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.

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].

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).

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

$$TDWW = 2139.4084443.10y^4 - 42406941511.776y^3 + 31521507.6319y^2 - 4913.33863y + 1.29003$$

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:

$$TDWW = 5124997.631647.10y^5 + 127372101954392y^4 - 126623482277.547y^3 + 62939529.68857y^2 - 15642.35137y + 1.55503$$

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

The data about TDWW ($\times 10^3$ m³) for Nišava district (Serbia) for the period 2006-2018 is presented in the following form:

$$TDWW = 5124997.631647.10y^5 + 127372101954392y^4 - 126623482277.547y^3 + 62939529.68857y^2 - 15642.35137y + 1.55503$$

with coefficients $R=0.7778$ and $R^2=0.6049$.
Table 5: Regression models for total discharged wastewater (×10^3 m^3) for Nišava district for the period 2006–2018

| No. | Model | Form of regression equation | R  | R^2 |
|-----|-------|-----------------------------|----|-----|
| 1   | PRM4  | TDWW=2139.4084442923.10^-4-4240694151.7762y+31521507.6319y^-10413.3386y^-1.29003y^0.7778 0.6049  |
| 2   | PRM5  | TDWW=5124997.831641.10^-1273721019.5392y+126623482277.547y^-72939529.68857y^-15642.35137y^-1.5503y^0.8207 0.6736  |
| 3   | PRM6  | TDWW=30938.78884488.10^-622.23739324.10^-11457.826286862.10^-75909172177.8344y^-28288393.7586y^-5622.32854y^-0.4656y^-0.8515 0.7251  |

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 ×10^3 + 92.23773924 ×10^-11 + 1273721019.5392y^-11457.826286862 ×10^-7 + 75909172177.8344y^-28288393.7586y^-5622.32854y^-0.4656y

(6)

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

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 (×10^3 m^3) | Calculated values for TDWW |
|------|------------------|---------------------------|
|      | For PRM4 | For PRM5 | For PRM6 |
| 2006 | 19,897 | 19,888,32 | 19,879,38 |
| 2007 | 18,940 | 17,782.42 | 18,848 | 18,918 |
| 2008 | 17,967 | 16,910.57 | 17,424 | 17,498 |
| 2009 | 15,954 | 16,946,41 | 16,744 | 16,734 |
| 2010 | 16,260 | 17,594,53 | 17,088 | 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 (×10^3 m^3) 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.

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).

Figures 5, 6, and 7, respectively, predict an increase values or growth of TDWW (Figures 5, 6, and 7, respectively). 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 (×10^3 m^3) | Calculated values for TDWW |
|------|------------------|---------------------------|
|      | For PRM4 | For PRM5 | For PRM6 |
| 2006 | 19,897 | 19,888,32 | 19,879,38 |
| 2007 | 18,940 | 17,782.42 | 18,848 | 18,918 |
| 2008 | 17,967 | 16,910.57 | 17,424 | 17,498 |
| 2009 | 15,954 | 16,946,41 | 16,744 | 16,734 |
| 2010 | 16,260 | 17,594,53 | 17,088 | 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 (×10^3 m^3) 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.

Conclusion

Values for DQDW (×10^3 m^3) 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
applied 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 (×10³ m³) for Nišava district (Serbia) for the period 2006–2018 increased from 19097 in 2006 to 19897 in 2018 (CGL=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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