Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2020 May 15; 8(E):127-132.
https://doi.org/10.3889/oamjms.2020.4764
eISSN: 1857-9655
Category: *E - Public Health*
Section: *Public Health Disease Control*

OPEN ACCESS

Trend Analysis of Total Affected Water and Total Discharged Wastewater of Nišava District (Serbia)

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Edited by: Sasho Stoleski
Citation: Pavićević N. Trend Analysis of Total Affected Water and Total Discharged Wastewater of Nišava District (Serbia). Open Access Maced J Med Sci. 2020 May 15; 8(E):127-132. https://doi.org/10.3889/oamjms.2020.4764
Keywords: Natural resources; Trend analysis; Statistical analysis; Polynomial regression model
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Received: 04-Apr-2020
Revised: 25-Apr-2020
Accepted: 03-May-2020

Funding: This research did not receive any financial support
Competing Interests: The authors have declared that no competing interests exist.

Abstract

BACKGROUND: Water, as a natural resource, is the most basic substance of life that has immeasurable significance for the living world, ecosystems, and planet Earth. It is consumed by plants, animals, and humans.

AIM: We aimed to preform a trend analysis of total affected quantities of water and total discharged wastewater (TDWW) of Nišava district (Serbia).

METHODS: In this paper, a trend analysis is given of total affected quantities of water, delivered quantities of drinking water (DQDW), total discharged wastewater (TDWW), wastewater discharges to wastewater systems, and number of households connected to the water supply network of Nišava district (Serbia).

RESULTS: The values for Nišava district (Serbia) for total affected quantities of water and DQDW for the period 2006–2018 and wastewater discharges to wastewater systems for the period 2009–2018 decreased, whereas the values for Nišava district (Serbia) for TDWW for the period 2006–2018 and number of households connected to the water supply network for the period 2007–2018 increased. The paper also provides regression models for approximation DQDW (eq. 1) and TDWW (eq. 2) for Nišava district (Serbia) for the period 2006–2018.

CONCLUSION: Values for total affected quantities of water (×103 m³) for Nišava district (Serbia) for the period 2006–2018, they decreased from 41740 in 2006 to 9931 in 2018.

Introduction

Natural resources (NR) are raw organic materials or substances, which are found in nature, and represent the general natural wealth which has usable value and can be used for industrial production and/or consumption [1], [2], [3], [4].

NR represents the natural wealth of a country or region include of minerals, petroleum, natural gas, coal, metals, stone, sand, air, sunlight, forests, land, and water. In papers George and Schillebeeckx [5] and George *et al*. [6] are given of the management of NR and in papers Nelson *et al*. [7], Smith [8], Tarasyev *et al*. [9], and Tarasyev *et al*. [10] are given of statistical analysis of different NR.

There are NRs that are subject to depletion by human use and that can be processed through various production processes into a product, and thus have a usable and economic value. Such NRs (PR) can be subdivided into four categories: Mineral and energy resources, soil and land resources, water resources, and biological resources.

Based on the type of reproducibility, many NRs are usually divided into two types [1] (Figure 1):

Renewable resources are resources that can naturally replenish (sunlight, air, forests, wind, water, etc.) and their consumption is slightly affected by human consumption and

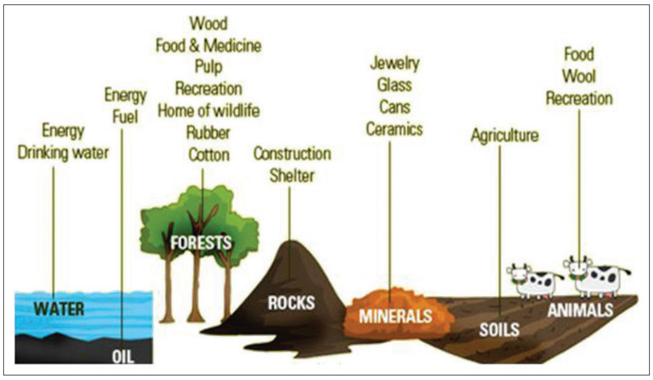

Figure 1: Different types of natural resources: Renewable and non-renewable resources

Non-renewable resources are resources that do not naturally form in the environment or are slowly being formed and/or renewed (land, fossil fuels, crude oil, natural gas, coal, various types of stone, metals, uranium, and other materials and minerals, etc.).

On the basis of origin, NRs are divided into two types [1]:

Biotic resources are resources obtained from the biosphere (living and organic material such as forests, animals, and plants), fossil fuels such as coal and petroleum because they are formed from decayed organic matter, etc., and

Abiotic resources are resources that come from non-living (inanimate), non-organic material (land, water, air, minerals, rare earth metals, and heavy metals, including ores, such as gold, iron, copper, and silver).

Water, as an NR, is the most basic material of life that has immeasurable significance for the living world, ecosystems, and planet Earth. Water is constantly circulating in nature between the Earth and the atmosphere, and at the same time, enables life to be maintained. Water moves, changing its appearance, but it never really disappears. The water that is consumed has been on Earth for hundreds of millions of years. It is consumed by plants, animals, and humans.

The most important characteristic of water is its quality, which is assessed by the so-called water quality index (WQI). Analysis of WQI index in different regional territories is presented in the following papers Aščić and Imamović [11], Bordalo *et al*. [12], Egborge and Benka-Coker [13], Elezović *et al*. [14], Selvam *et al*. [15], and Von der Ohe *et al*. [16], WQI index as management tool is given in paper Ferreira *et al*. [17], and as classification tool is given in papers Boyacioglu [18] and Kannel *et al*. [19], for water quality is given in papers Gupta *et al*. [20] and Kaurish and Younos [21], for prediction of WQI index is given in paper Rene and Saidutta [22], etc.

In paper is given a trend analysis of total affected quantities of water and total discharged wastewater (TDWW) of Nišava district (Serbia).

Data and Methods

Data on values of total affected quantities of water, TDWW, etc., 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 [23], [24], [25], [26], [27], with significant calculations by the authors.

In the Nišava district, the following municipalities are (Figure 2): Niš, Aleksinac, Gadžin Han, Doljevac, Merošina, Ražanj, and Svrljig.

The total area for Nišava district in 2018 is 2728 km^2. Population in Nišava district in 2002 is 381757 (of these men are: 187780 and the woman is: 193977) and in 2018 is 362331 [27], which is less for 19426 or compound annual growth rate (CAGR)=−0.33% and cumulative growth index (CGI)=94.91%.

In 2018, the total number of employees registered was 106931 (of these men: 55063 and the women: 51868), while the number of employees per 1000 population was 295.

Figure 2: Map of Nišava district

For the trend analysis, we used the following parameters: AGR, CAGR, and CGI described in the papers Dašić [28], Dašić *et al*., [29], Tošović *et al*., [30], Turmanidze *et al*., [31], etc.

Standard statistical analysis methods and MS-Excel software system were used to calculate the statistical descriptions parameter, graphical representation of data, and approximation of the total affected quantities of water and TDWW for Nišava district (Serbia) [32], [33], [34].

Results and Discussion

In Table 1, data are given about total affected quantities of water, delivered quantities of drinking water (DQDW), TDWW, wastewater discharges to wastewater systems, and number of households connected to the water supply network for Nišava district (Serbia) for the period 2006–2018 [23], [24], [25], [26], [27].

Trend analysis for total affected quantities of water (×10^3 m³) for Nišava district (Serbia) for the period 2006–2018 is shown in Figure 3.

The data about total affected quantities of water (×10^3 m³) for Nišava district (Serbia) for the period 2006–2018 changed in intervals from 5783 to 41740, with arithmetic mean AM=25771.85 and median is Med=37782. Standard deviation is SD=15831.5 and coefficient of variation is CoV=61.43.

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

Year	Total affected quantities of water (×103 m³)	Delivered quantities of drinking water (×103 m³)	Total discharged waste water (×103 m³)	Wastewater discharges to wastewater systems (×103 m³)	Number of households connected to the water supply network
2006	41740	23777	19097	-	1423 (km)
2007	40536	25418	18940	-	58752
2008	38965	24214	17967	-	57876
2009	37782	22982	15964	15964	58730
2010	38045	23099	16820	16820	59593
2011	40051	22918	16287	16287	60907
2012	41314	23030	22393	16661	63530
2013	8871	23018	22374	16576	62923
2014	5783	19805	19411	16046	62930
2015	10378	23306	22669	17181	63391
2016	10726	21775	21247	16765	63475
2017	10912	21180	20651	15887	63482
2018	9931	20402	19897	15357	63494

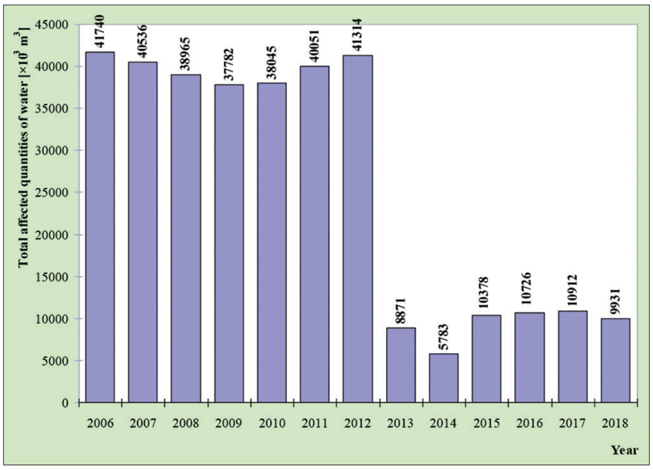

Figure 3: Trend analysis for total affected quantities of water (×10^3 m³) for Nišava district (Serbia) for the period 2006-2018

Values of trend analysis are CGI=23.79% in 2018 compared to 2006 and CAGR=−8.58% per year for the period 2006–2018.

Trend analysis for DQDW (×10^3 m³) for Nišava district (Serbia) for the period 2006-2018 is shown in Figure 4.

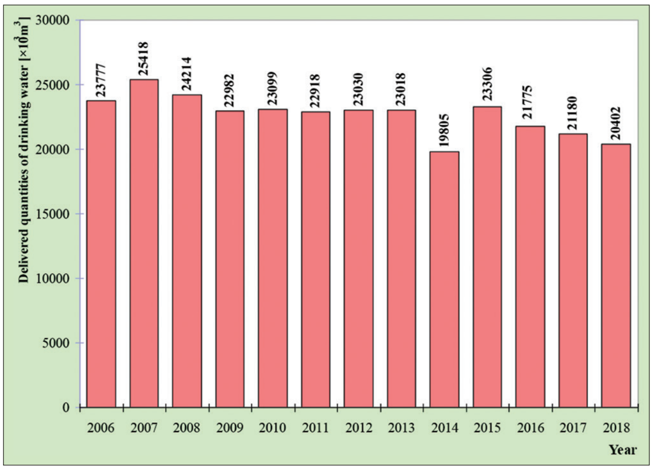

Figure 4: Trend analysis for delivered quantities of drinking water (×10^3 m³) for Nišava district (Serbia) for the period 2006–2018

The data about DQDW (×10^3 m³) 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.

The data about DQDW (×10^3 m³) for Nišava district (Serbia) for the period 2006–2018 can be approximated using a linear regression model (LRM) which has the form (Figure 5):

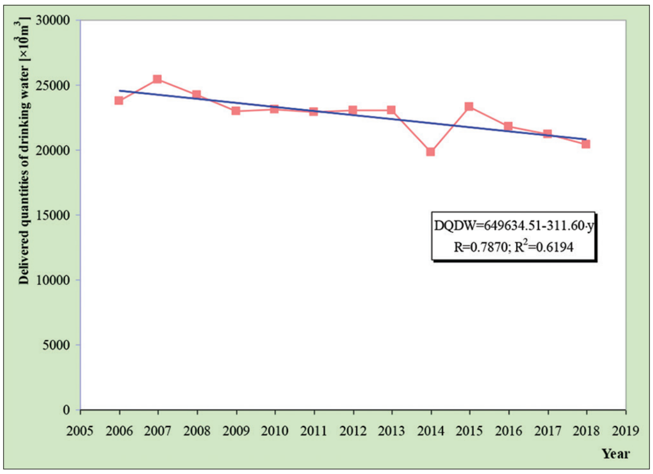

Figure 5: Approximated delivered quantities of drinking water (×10^3 m³) for Nišava district (Serbia) for the period 2006–2018 using linear regression

$$DQDW=649634.51–311.60×y \quad (1)$$

With coefficient of correlation is R=0.7870, coefficient of determination is R^2=0.6194.

Where: y–year and DQDW–DQDW (×10^3 m³).

Trend analysis for TDWW (×10^3 m³) for Nišava district (Serbia) for the period 2006–2018 is shown in Figure 6.

The data about TDWW (×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.

The data about TDWW (×10^3 m³) for Nišava district (Serbia) for the period 2006–2018 can be approximated using 6th-degree polynomial regression model (PRM6) which has the form (Figure 7):

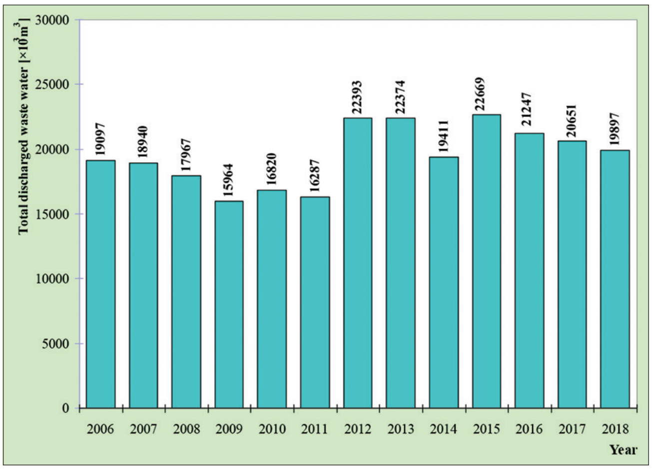

Figure 6: Trend analysis for total discharged wastewater (×10^3 m³) for Nišava district (Serbia) for the period 2006–2018

$$TDWW=-309387888448786\times10^5+92237739224067200\times y-114578282688620\times y^2+75909172177.8344\times y^3-28288393.7586\times y^4+5622.3854\times y^5-0.4656\times y^6 \quad (2)$$

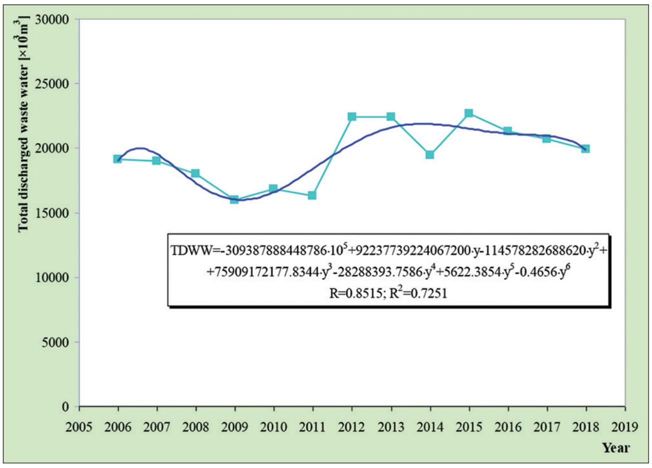

Figure 7: Approximated (total discharged wastewater) (×10^3 m³) for Nišava district (Serbia) for the period 2006–2018 using 6th-degree polynomial regression model

With coefficient of correlation is R=0.8515, coefficient of determination is R^2=0.7251.

Where: y–year and TDWW–TDWW (×10^3 m³).

Trend analysis for wastewater discharges to wastewater systems (×10^3 m³) for Nišava district (Serbia) for the period 2009–2018 is shown in Figure 8.

The data about wastewater discharges to wastewater systems (×10^3 m³) for Nišava district (Serbia) for the period 2009–2018 changed in intervals from 15357 to 17181, with AM=16354.40 and Med=16431.5. Standard deviation is SD=545.39 and CoV=3.34.

Values of trend analysis are CGI=96.20% in 2018 compared to 2009 and CAGR=−0.24% per year for the period 2009–2018.

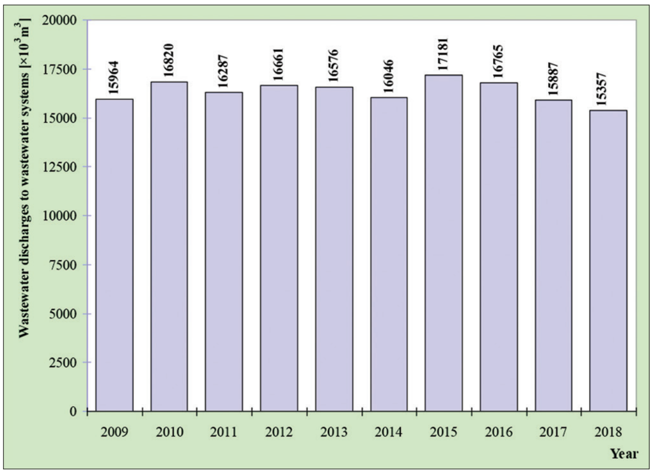

Figure 8: Trend analysis for wastewater discharges to wastewater systems (×10^3 m³) for Nišava district (Serbia) for the period 2009–2018

Trend analysis for number of households connected to the sewer network for Nišava district (Serbia) for the period 2007–2018 is shown in Figure 9.

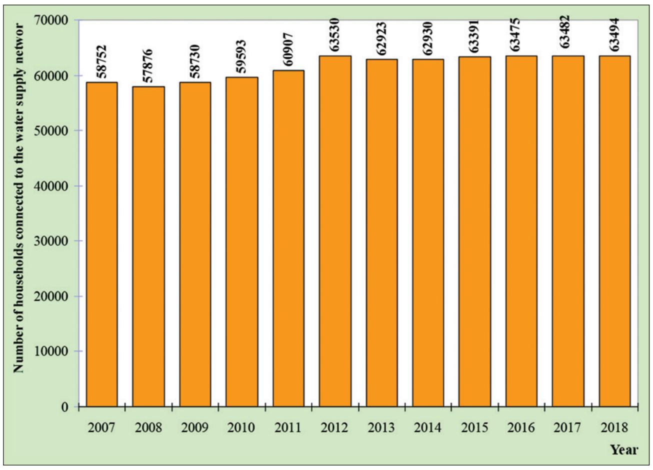

Figure 9: Trend analysis for number of households connected to the sewer network for Nišava district (Serbia) for the period 2007–2018

The data about number of households connected to the sewer network for Nišava district (Serbia) for the period 2007–2018 changed in intervals from 57876 to 63530, with AM=61590.25 and Med=62926.5. Standard deviation is SD=2252.67 and CoV=3.66.

Values of trend analysis are CGI=108.07% in 2018 compared to 2007 and CAGR=0.49% per year for the period 2007–2018.

Conclusion

Values for total affected quantities of water (×10^3 m³) for Nišava district (Serbia) for the period 2006–2018, they decreased from 41740 in 2006 to 9931 in 2018 (CGI=23.79% in 2018 compared to 2006 and CAGR=−8.58% per year).

Values for DQDW ($\times 10^3$ m³) for Nišava district (Serbia) for the period 2006–2018, they decreased from 23777 in 2006 to 20402 in 2018 (CGI=85.81% in 2018 compared to 2006 and CAGR=−0.95% per year).

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

Values for wastewater discharges to wastewater systems ($\times 10^3$ m³) for Nišava district (Serbia) for the period 2009–2018, they decreased from 15964 in 2009 to 15357 in 2018 (CGI=96.20% in 2018 compared to 2006 and CAGR=−0.24% per year).

Values for number of households connected to the sewer network for Nišava district (Serbia) for the period 2007–2018, they increased from 58752 in 2007 to 63494 in 2018 (CGI=108.07% in 2018 compared to 2006 and CAGR=0.49% per year).

Values for DQDW ($\times 10^3$ m³) for Nišava district (Serbia) for the period 2006-2018 is approximated by LRM (eq. 1), with R=0.7870 and R^2=0.6194.

Values for TDWW ($\times 10^3$ m³) for Nišava district (Serbia) for the period 2006–2018 is approximated by 6PRM6 (eq. 2), with R=0.8515 and R^2=0.7251.

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