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Modeling and Prognosis of the Strouma River Pollution

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Summary: A model for analysis and prognosis of river quality has been developed, which is a modified method of the time series analysis has been applied for an assessment and prognosis of water pollution of the Strouma river. The following indexes of the water pollution of the Strouma river have been investigated: *BOD*, *oxidation*, *soluble* and *insoluble* substance – the village of Marino Pole. Periodical seasonal and annual pollution variations have been determined, as well as basic tendencies in the evolution of the water quality for the period from years 2001 to 2003. A prognosis of the river pollution for the year 2004 has been made. The received results show the offered times series analysis modified method successfully could be used for modeling and prognosis of the water pollution of the river ecosystems.

Keywords: Modeling, Modified Times Series Analysis Method, Prognosis, Strouma River.

1. INTRODUCTION

Retrospective analysis, present state survey and pollution prognosis for a long-term period are three interrelated stages in investigating the state in functioning of river ecosystems. The analysis of the information about water pollution gives a chance to define the trends and basic tendencies in the evolution of water quality for the determined period. On the basis of the retrospective analysis, it is necessary to make a prognosis of the pollution dynamic for a long period (from 1 to 3 years). Models of time series analysis (TSA) are used for evaluation of environmental pollution [1, 2, 7].

The TSA for water quality is a part of the retrospective modeling of water ecosystem functioning carried out with deterministic methods. Bearing in mind the hydrological, hydrochemical and hydrobiological characteristics in the river ecosystems and the dynamics of the point and diffuse pollutants in the catchment, a conclusion may be drawn, that the analysis of the temporary series is suitable for the retrospective assessment of water quality. The integration of determination and statistical models for water quality is necessary means of water ecosystem management. These models use information from environmental monitoring, and their realizations [1].

The modified time series analysis method is successfully applied for modeling and prognosis of the Strouma river pollution of the following indexes: *ammonia nitrogen, nitrate nitrogen and phosphate* at the end of Bulgarian part at the border with Greece – the village of Marino Pole [5].

The aim of this paper is modeling and prognoses of the Strouma river pollution on indexes are not included in the previous investigations by a modified time series analysis method.

2. MODELING AND PROGNOSIS OF THE POLLUTION OF THE STROUMA RIVER

The pollution dynamics of the Strouma river is carried out on the base on the data obtained by the National System for Ecological Monitoring [3, 4] for the period form years 2001 to 2004. We examined the water quality of the Strouma river in point at the end of Bulgarian part at the border with Greece – the village of *Marino Pole*. The following indexes of the biogenic water pollution are determined: *BOD, oxidation, soluble* and *insoluble* substance.

The model for retrospective analysis of the pollution of the Strouma river for the period from years 2001 to 2003 and for prognosis of the pollution for the 2004 year.

The model for analysis and prognosis of the Strouma pollution on the investigated indexes has the following type [6]:

$$\mathbf{x} = a_0 + a_1 t + \ldots + a_r t^r + \sum_{k=0}^{p} b_k \sin\left(\frac{2\pi}{c_k} t + d_k\right) \tag{1}$$

where: $\mathbf{x}$ = [*BOD*, *Oxidation*, *Soluble substance*, *Insoluble substance*]^T; r – the degree of polynomial; p – number of the periodical components.

At the pollution assessment it is useful the basic to be determined. It shows the tendencies in the river pollution for investigated indexes and it is a linear function on the time [7]:

$$\mathbf{x} = A_0 + A_1 t \tag{2}$$

An algorithm and program is developed of the modified TSA [8].

At determining of the trend function degree in (1) it is proves the best results a polynomial from second degree gives, i.e. r = 2. For periodical functions the best results four numbers show, i.e. p = 3 (the comparison is made on the Fisher function). The calculated coefficients in the models (1) and (2 in each investigated indexes are shown in Table 1.

Table 1. Coefficients in the models for modeling and prognosis

BOD	A_0	A_1	
Main trend	367.7506	-0.18355	
Trend	a_0	a_1	a_2
	-179684.6	179.599	-0.04488
Periodical Functions, k=0,…,3	b_k	c_k	d_k
	0.36110	3.96826	2.00095
	-0.24029	1.72000	9.54667
	1.72987	1.25948	-2.23670
	-0.10578	0.12207	3.68984
Oxidation	A_0	A_1	
Main trend	253.6839	-0.12764	
Trend	a_0	a_1	a_2
	1189873.0	-1187.948	0.29651
Periodical Functions, k=0,…,3	b_k	c_k	d_k
	3.39869	3.96851	0.29480
	3.55118	1.86512	30.77954
	-1.69107	1.26458	2.67149
	0.03561	0.12462	3.68984

Soluble substance	A_0	A_1	
Main trend	196.7408	0.09860	
Trend	a_0	a_1	a_2
	566135.1	-565.19360	0.141063
Periodical Functions, k=0,…,3	b_k	c_k	d_k
	1.39200	3.96898	0.57149
	1.21669	1.87073	13.22404
	1.09538	-1.25231	16.03590
	-0.00500	0.13048	0.68984
Insoluble substance	A_0	A_1	
Main trend	-297.3050	0.14811	
Trend	a_0	a_1	a_2
	259653.1	-259.41350	0.06480
Periodical Functions, k=0,…,3	b_k	c_k	d_k
	0.92785	3.96906	0.73351
	1.34151	1.87357	4.27546
	0.60636	1.26080	-0.17838
	0.02295	0.11590	3.68984

Table 2 shows the experimental correlation coefficients – R^2, experimental function of Fisher – F_E, relative error – S_L and test for trend – T' for the studied indices on modeling.

Table 2. Statistical coefficient of the models

Parameter	R^2	F_E	T'	S_L
BOD	0.8351	1.1965	0.3481	14.6942
Oxidation	0.9368	1.0829	0.1322	6.8596
Soluble substance	0.9358	1.0656	0.2844	10.5156
Insoluble substance	0.9675	1.0320	0.1695	22.2370

The results from the modeling and prognosis of the pollution of the Strouma river at the village of Marino Pole are shown in Fig. 1 to Fig. 4.

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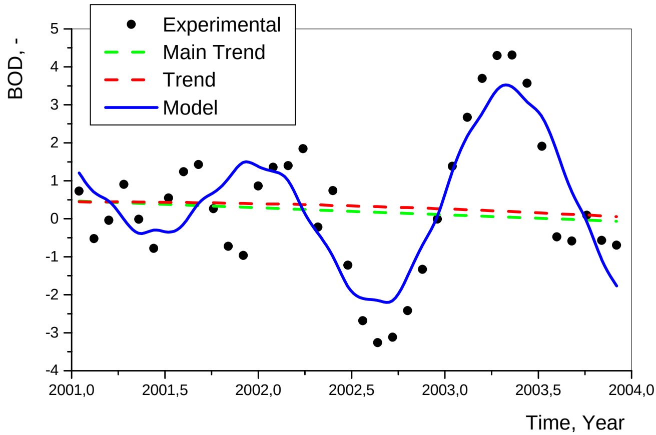
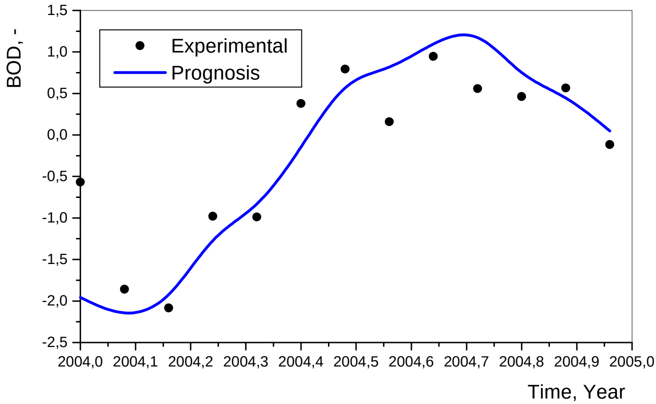
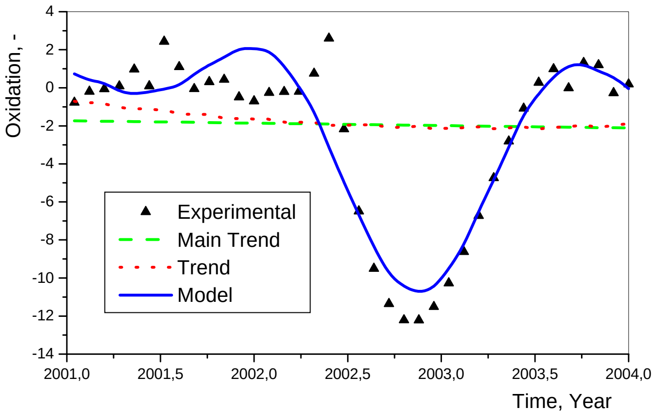


a) Modeling

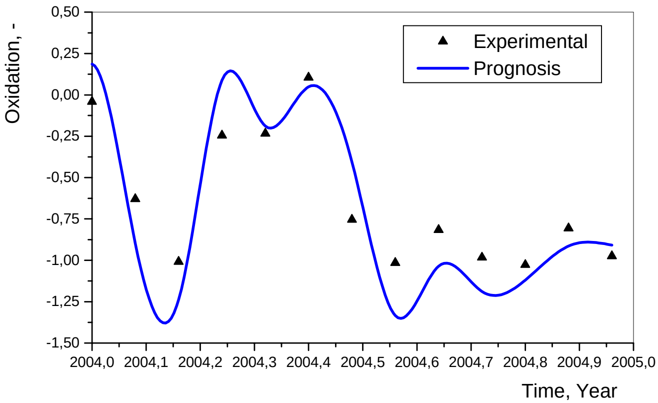


b) Prognosis

Fig. 1. Modeling and prognosis of the BOD

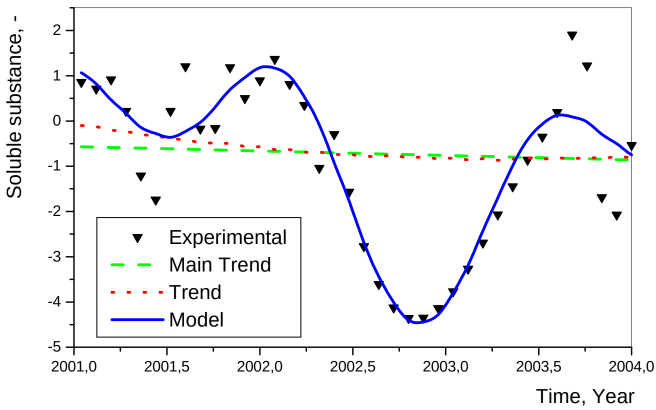


a) Modeling

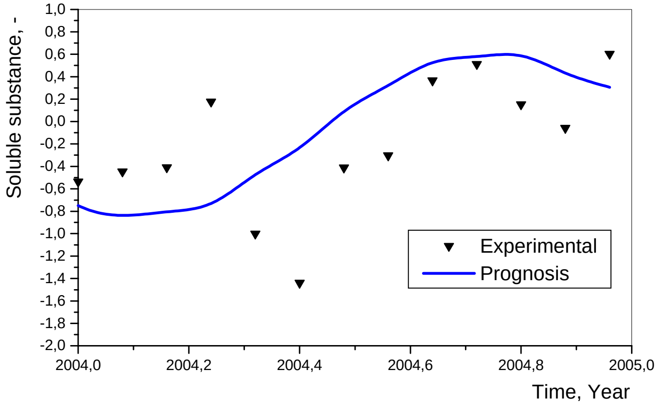


b) Prognosis

Fig. 2. Modeling of and prognosis of the Oxidation

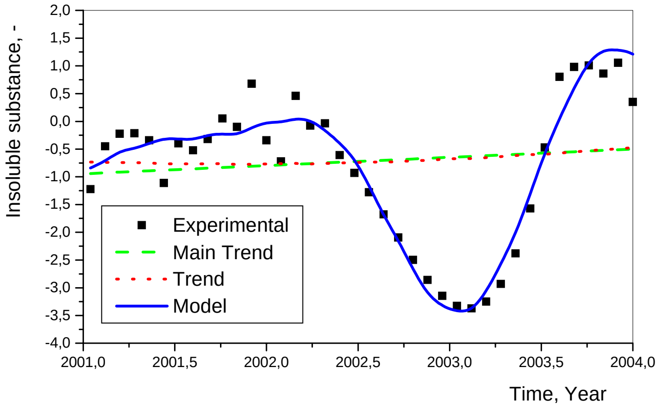


a) Modeling

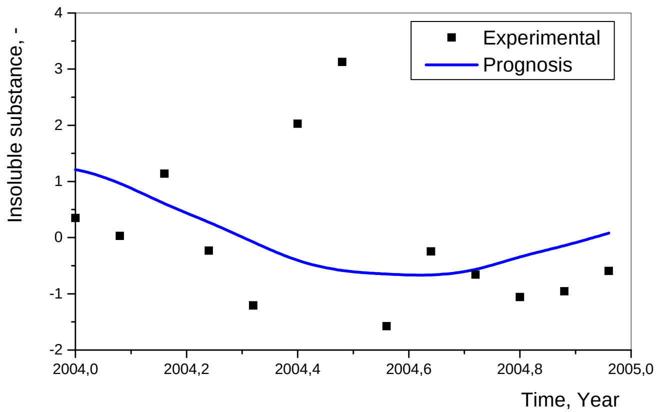


b) Prognosis

Fig. 3. Modeling of and prognosis of the Soluble substance



a) Modeling



b) Prognosis

Fig. 4. Modeling and prognosis of the Insoluble substance

3. RESULTS AND DISCUSSION

The theoretical values of the correlation coefficient and Fisher function for 95% confidence coefficient at the respective degrees of freedom are:

$$R^2_T(95\%, 29) = 0.349,\ F_T(95\%, 27, 30) = 2.12 \text{ and } T = 1.705.$$

The calculated trend *T'* of the investigated pollution indices range in the interval from 0.13 to 0.35 and are smaller than the theoretical trend *T*. The calculated correlation coefficients of the investigated pollution indices range in the interval from 0.84 to 0.97 and are larger than the theoretical correlation coefficient. The calculated Fisher function of the investigated pollution indices range in the interval from 1.03 to 1.20 and are smaller than the theoretical function. The relative error S_L varies from 6.86 to 22.24 for different pollution indices, which proves the adequacy of the models (Table 2). This fact proves that the elaborated trend functions characterize adequately the tendencies of the pollution dynamics of the Strouma river.

The results for modeling of the main trend and trend (Fig. 1a to Fig. 3a) show decrease of the water pollution of the Strouma river on the indexes: *BOD*, *Oxidation* and *Soluble Substance* in the examined period. At the Insoluble Substances a feebly increase is observed for the determined period (Fig. 4a).

From obtained results for the Strouma river prognosis (Fig. 1b – Fig. 4b) it is shown the offered modified TSA with can successfully used for prognosis of the Strouma river pollution for the investigated one-year period as the basic tendencies for decrease of the pollution are preserved.

The model and prognosis results of the pollution are less than the Limiting Permissible Concentrations

4. CONCLUSION

From the modeling, analysis and prognosis of the pollution of the Strouma river the following conclusions can be drawn:

1. A model for analysis and prognosis of the river pollution is developed, which adequately expresses the dynamics of the pollution for a defined period.
2. The elaborated model for prognosis of water pollution gives a possibility to determine the tendencies of the pollution evolution of the Strouma river and to make a prognosis for a longer period. The model allows the quantitative assessment of the dynamics of the impact from point pollutant on the river ecosystems, as well as the planning of the necessary measures.

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