19th Int. Workshop on IFSs, Burgas, 4–6 June 2015
Notes on Intuitionistic Fuzzy Sets
ISSN 1310–4926
Vol. 21, 2015, No. 2, 118–125

Application of InterCriteria analysis to the Mesta River pollution modelling

Tatiana Ilkova, Mitko Petrov

Institute of Biophysics and Biomedical Engineering
Bulgarian Academy of Sciences
105, Acad. G. Bonchev Str., Sofia 1113, Bulgaria
e-mails: {tanja, mpetrov}@biomed.bas.bg

Abstract: In this paper we present the recently proposed approach InterCriteria Analysis (ICA) for the Mesta River pollution modelling in Bulgaria. The approach is based on the apparatus of the index matrices and the intuitionistic fuzzy sets. We have applied the ICA to establish the basic pollution relations (the model structure) based on different criteria involved in the Mesta River. The results have shown the criteria are independent, they are time functions. Based on this we have developed an adequate mathematical model of the Mesta River pollution. The Method of the least squares is used for a parametric identification.

Keywords: InterCriteria analysis, Pollution modelling, the Mesta River.

AMS Classification: 03E72, 93A30, 92D40.

1 Introduction

The Mesta River flows through Bulgaria and Greece. It springs from the Rila Mountains and flows into the Aegean Sea near the island of Thasos. Its right tributary the Bela Mesta Spring is considered for its beginning. The Bela Mesta Spring is located at altitude of 2240 m, near the Granchar Lake in the East Rila Mountain in Bulgaria. The Mesta River catchment is shown in Figure 1.

The waster in the Mesta River goes through anthropogenic impacts when the altitude is below 1100 m. The impacts are as stronger as closer the river section is to the Greece border. This is the exact reason why the water quality is examined at Hadzhidimovo and Filipovo measuring stations where the integral impact of the catchment area is assessed.

The influence over the water quality of the Mesta River has different agents and the most important ones are: the direct influx of sewage of some living places; the influx of industry waste waters into the river and its tributaries; domestic wastes; wastes of different activities at the river runways; non-point pollution from agricultural activity at the region, etc. There is not any industry activity near the catchment which can directly influence the surface water quality [10, 11, 12].

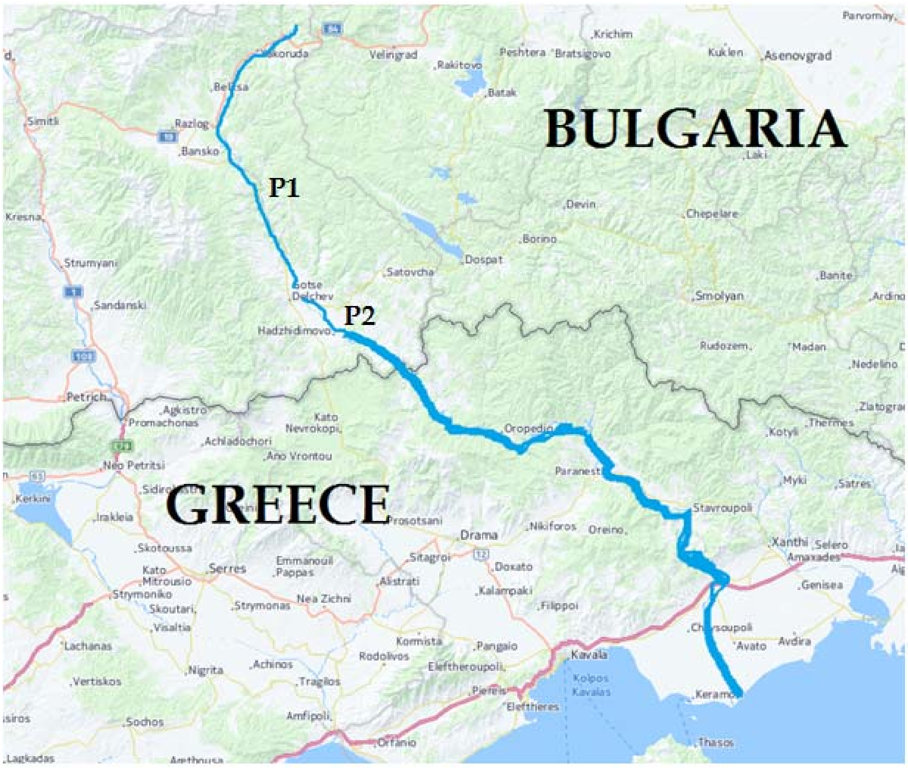

Figure 1. The Mesta River catchment area

Trophic pollution is proposed in [11] a model for the dynamics of the integral index determining the level of the stream water. The integral index is based on the oxygen balance, organic and nutrients loading, suspended and dissolved substances. This index is applied for assessing the level of the trophic pollution of the Mesta River at Hadzhidimovo located in the end of the Bulgarian section of the river. Also a modified method of time series analysis is applied.

Atanassov et al. [1] introduced a new approach, namely ICA for decision making. It is based on the apparatus of index matrices (IMs) [2, 3, 4] and intuitionistic fuzzy sets (IFs) [5, 6]. The method for ICA makes it possible to compare certain criteria or objects estimated by them. Atanassova et al. [7, 8, 9] applied ICA in an EU member states competitiveness analysis. They carried out a temporal and threshold analysis, Ilkova et al. [13] have used ICA for modelling of bioprocess.

In this paper we investigate a modelling of the Mesta River pollution of the following indexes for the organic and biogenic water pollution: ammonia and nitrate nitrogen, biochemical oxygen demand, permanganate oxidation, dissolved and unsolved substances, and dissolved oxygen.

The aim of the study is to use the ICA for modelling of the Mesta River pollution in its Bulgarian part considering different indices. The method is based on index matrices, IMs [2, 3, 4] and intuitionistic fuzzy sets, IFSs [9], and intuitionistic fuzzy pairs, IFPs, [6, 7].

2 Results and discussion

The modelling of the pollution dynamics of the river ecosystem of the Mesta River has been carried out on the basis of the information from the National System for Ecological Monitoring – West Aegean Sea River Basin Directorate, Blagoevgrad. The following indices have been examined: ammonia and nitrate nitrogen (respectively NH_4-N and NO_3-N), biochemical oxygen demand (BOD), $KMnO_4$ – permanganate oxidation, dissolved oxygen (DO), dissolved and unsolved substances (respectively DS and US) at Hadzhidimovo – P2 at Filipovo – P1 of the Mesta River.

Our colleagues have developed a program for the purpose of applying the method. The results are shown in Table 1.

Table 1. The values calculated of pair $\langle \mu_{C_iC_j}, \nu_{C_iC_j} \rangle$

	NH_4-N	NO_3-N	BOD	$KMnO_4$	DO	DS	US
NH_4-N		⟨0.3823,0.5907⟩	⟨0.6213, 0.3538⟩	⟨0.4455,0.5321⟩	⟨0.4049,0.5626⟩	⟨0.6095,0.3660⟩	⟨0.5444,0.4280⟩
NO_3-N	⟨0.3823,0.5907⟩		⟨0.6401, 0.3449⟩	⟨0.7029,0.2836⟩	⟨0.6895,0.2883⟩	⟨0.6037,0.3818⟩	⟨0.5315,0.4496⟩
BOD	⟨0.6213,0.3538⟩	⟨0.6401,0.3449⟩		⟨0.6157,0.3732⟩	⟨0.6062,0.3740⟩	⟨0.5750,0.4129⟩	⟨0.4865,0.4974⟩
$KMnO_4$	⟨0.4455,0.5321⟩	⟨0.7029,0.2836⟩	⟨0.6157,0.3732⟩		⟨0.6026,0.3793⟩	⟨0.6643,0.3256⟩	⟨0.5380,0.4488⟩
DO	⟨0.4049,0.5626⟩	⟨0.6895,0.2883⟩	⟨0.6062,0.3740⟩	⟨0.6026,0.3793⟩		⟨0.4162,0.5653⟩	⟨0.4501,0.5280⟩
DS	⟨0.6095,0.3660⟩	⟨0.6037,0.3818⟩	⟨0.5750,0.4129⟩	⟨0.6643,0.3256⟩	⟨0.4162,0.5653⟩		⟨0.4751,0.5106⟩
US	⟨0.5444,0.4280⟩	⟨0.5315,0.4496⟩	⟨0.4865,0.4974⟩	⟨0.5380,0.4488⟩	⟨0.4501,0.5280⟩	⟨0.4751,0.5106⟩	

In Figure 2 we have presented the dependencies between μ and ν.

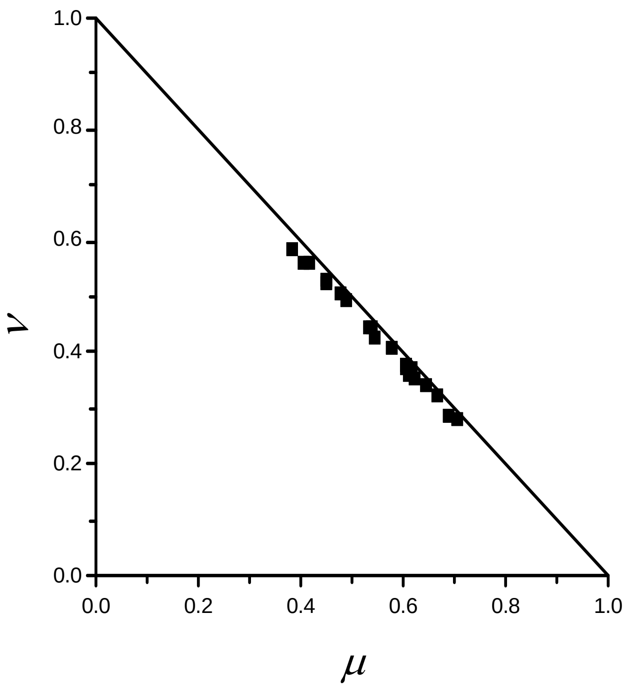

Figure 2. Relations between μ and ν for the different criteria

With the help of Table 1 and Figure 2, we will investigate the dependencies between the indices for the organic and biogenic water pollution. The indices for water pollution are: ammonia and nitrate nitrogen, biochemical oxygen demand, permanganate oxidation, dissolved oxygen, dissolved and unsolved substances.

The low value of $\mu \in [0.382, 0.703]$, and the high value of $\nu \in [0.284, 0.591]$, as the low value of uncertainty $\pi \in [0.0111, 0.0325]$ (Table 1 and Figure 2) shows the investigated criteria (the organic and biogenic water pollution) are independent on each other and they cannot be excluded off the river water quality determination. In all case we have dissonance.

The indexes are not correlated between each other and they will be a time function, i.e. $f_i(t)$. We have used MATLAB 7 to determine the type of the functions $f_i(t)$:

$$\begin{aligned} f_i(t) = {} & a_{i,13}t^{13} + a_{i,12}t^{12} + a_{i,11}t^{11} + a_{i,10}t^{10} + a_{i,9}t^{9} + a_{i,8}t^{8} + \\ & + a_{i,7}t^{7} + a_{i,6}t^{6} + a_{i,5}t^{5} + a_{i,4}t^{4} + a_{i,3}t^{3} + a_{i,2}t^{2} + a_{i,1}t + a_{i,0} \end{aligned}, \text{ for } i = 1, ..., 7.$$

Based on the real and model data we have developed a program with the help of the method of least squares. With this program we define the coefficient in the model.

The model and experimental data are shown from Figure 3 to Figure 9.

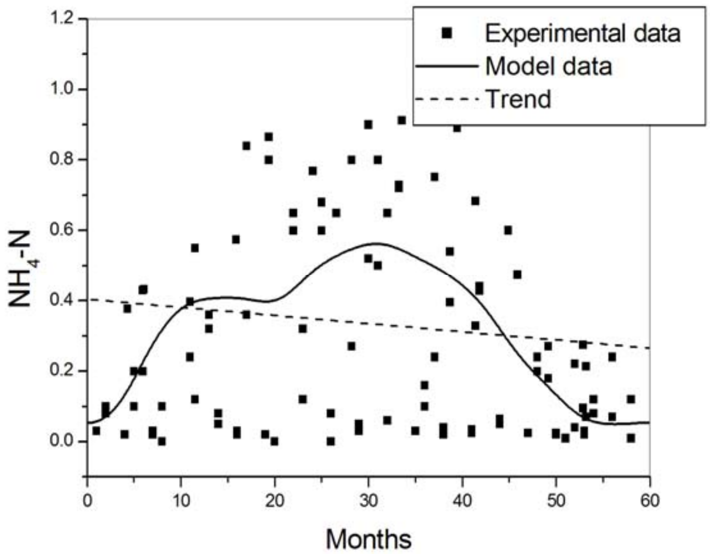

Figure 3: Experimental and model data for the ammonia nitrogen

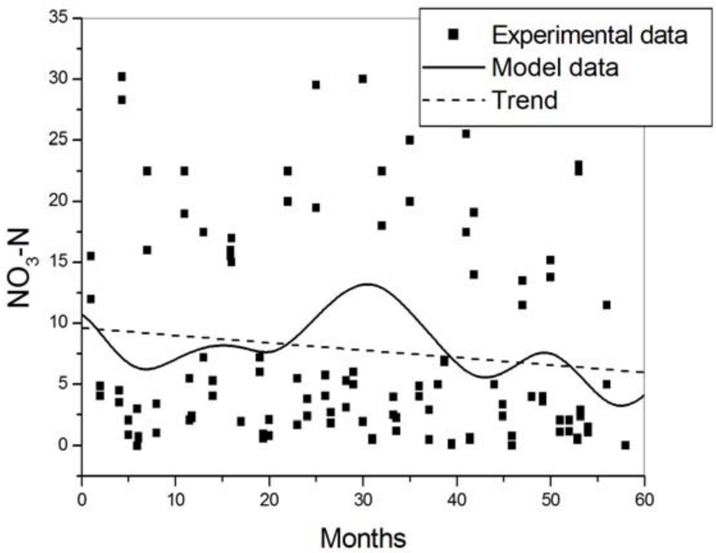

Figure 4: Experimental and model data for the nitrate nitrogen

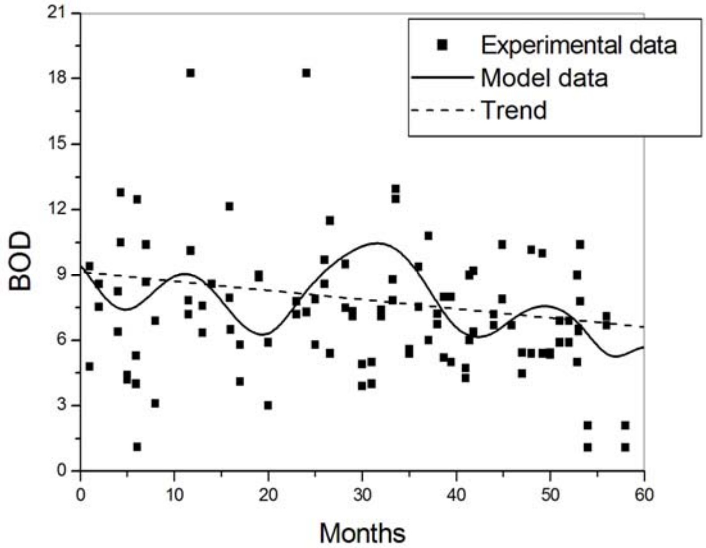

Figure 5: Experimental and model data for BOD

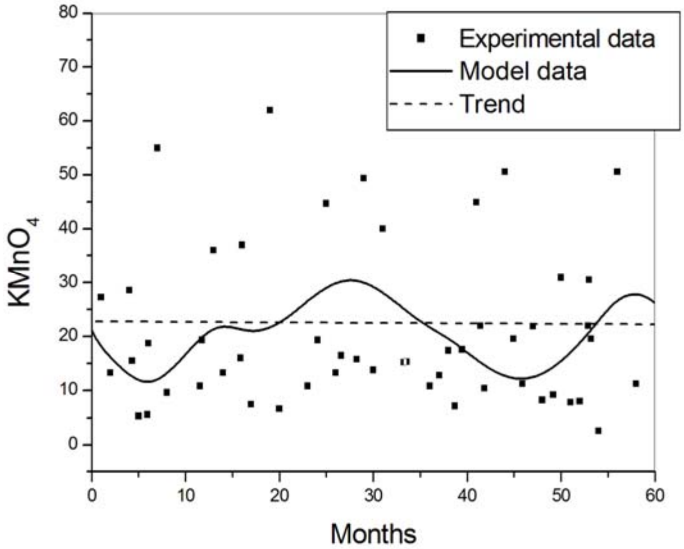

Figure 6: Experimental and model data for $KMnO_4$

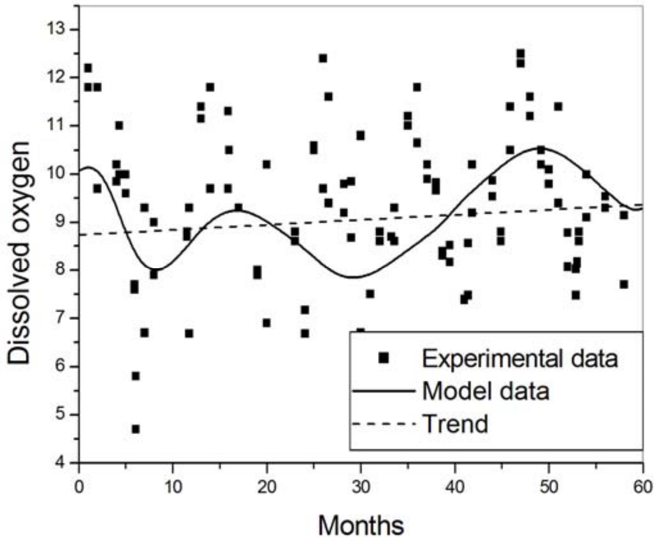

Figure 7: Experimental and model data for the dissolved oxygen

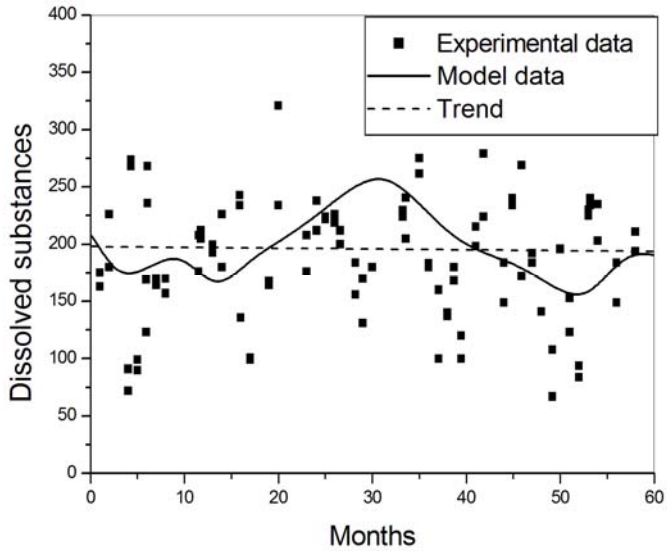

Figure 8: Experimental and model data for the dissolved substances

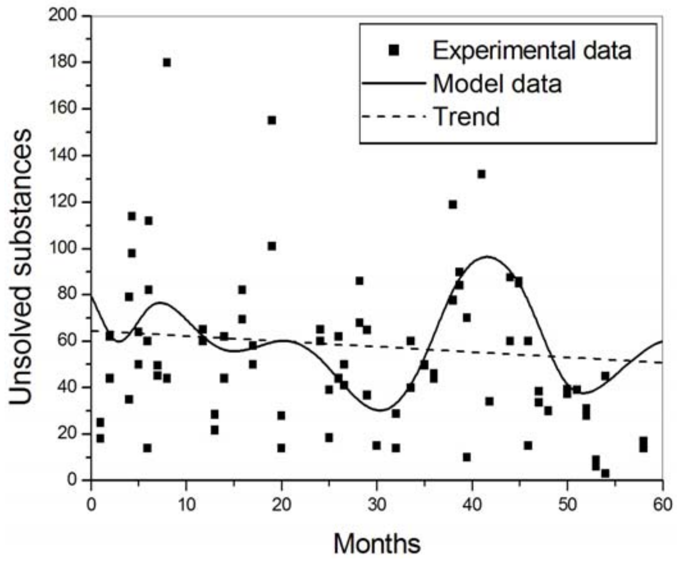

Figure 9: Experimental and model data for the unsolved substances

We have developed a validation of the models by the experimental correlation coefficient (R_E^2). The experimental correlation coefficients for models (1)–(7) are from R_E^2 = 0.584 to R_E^2 = 0.691. The tabular correlation coefficient is $R_T^2 = 0.262$, [14]. The results show that the models predict experimental data and the models are adequate.

3 Conclusion

With the help of the InterCriteria Analysis we have established the basic dependences between the different pollution criteria – ammonia and nitrate nitrogen, biochemical oxygen demand, permanganate oxidation, dissolved oxygen, dissolved and unsolved substances of the Mesta

River at the two specific points. The criteria are not in positive consonance between each other (they are independent) and they are functions of time. In this way we have developed the models of the pollution dynamic. The models are adequate to experimental data, as assessed using the correlation coefficient.

The modelling results (especially the trend function) show that negative tendencies of the river water quality have not been established. The water quality of the Mesta River for the investigated criteria is within the limits of IInd and IIIrd category according to the European standards.

Acknowledgements

The authors are thankful for the support provided by the project DFNI-I-02-5/2014 "InterCriteria Analysis – New Approach for Decision Making", funded by the National Science Fund, Bulgarian Ministry of Education and Science.

References

[1] Atanassov, K., Mavrov, D., & Atanassova, V. (2014) Intercriteria decision making: A new approach for multicriteria decision making, based on index matrices and intuitionistic fuzzy sets, *Issues in IFSs and GNs*, 11, 1–8.

[2] Atanassov, K. (1987) Generalized index matrices, *Comptes rendus de l'Academie Bulgare des Sciences*, 40(11), 15–18.

[3] Atanassov, K. (2010) On index matrices, Part 1: Standard cases, *Advanced Studies in Contemporary Mathematics*, 20(2), 291–302.

[4] Atanassov, K. (2010) On index matrices, Part 2: Intuitionistic fuzzy case, *Proceedings of the Jangjeon Mathematical Society*, 13(2), 121–126.

[5] Atanassov, K. (2012) *On Intuitionistic Fuzzy Sets Theory*, Springer, Berlin.

[6] Atanassov, K., Szmidt, E., & Kacprzyk, J. (2013) On intuitionistic fuzzy pairs, *Notes on Intuitionistic Fuzzy Sets*, 19(3), 1–13.

[7] Atanassova, V., Doukovska, L., Mavrov, D., Atanassov, K. (2014) InterCriteria decision making approach to EU member states competitiveness analysis: Temporal and threshold analysis. *Proceedings of 7th IEEE International Conference Intelligent Systems IS'2014,* 24-26 September 2014, Warsaw, Poland, Vol. 1, 97–106.

[8] Atanassova, V., Mavrov, D, Doukovska, L., & Atanassov, K. (2014) Discussion on the threshold values in the InterCriteria decision making approach, *Notes on Intuitionistic Fuzzy Sets*, 20(2), 94–99.

[9] Atanassova, V., Doukovska, L., Atanassov, K., & Mavrov. D. (2014) Intercriteria decision making approach to EU member states competitiveness analysis, *Proc. of 4th International Symposium on Business Modeling and Software Design, 24–26 June 2014*, *Luxembourg*, *Grand Duchy of Luxembourg*, 289–294.

[10] Diadovski, I., Atanassova, M., & Ivanov, I. (2007) Integral assessment of climate impact on the transboundary Mesta River flow formation in Bulgaria, *Environmental Monitoring and Assessment*, 127(1–3), 383–388.

[11] Diadovski, I., Petrov, M., Ilkova, T., & Ivanov I. (2005) A model for the Mesta River pollution assessment based on the integral indices, *Chemical and Biochemical Engineering Quarterly*, 19(3), 291–296.

[12] West Aegean Sea River Basin Directorate (2014) *Plan for Mesta River Basin Management*, `http://www.wabd.bg/bg/docs/plans/MS/RBMP_MSI.pdf`

[13] Ilkova, T., & Petrov, M. (2015) Intercriteria analysis for identification of *Escherichia coli* fed-batch mathematical model, *Journal of Int. Scientific Publications: Materials, Methods & Technology* (in press).

[14] Stoyanov, S., (1983) *Optimisation of Technological Objects*, Technika, Sofia (in Bulg.).