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INTEGRAL ASSESSMENT OF THE TRANSBOUNDARY MESTA RIVER TROPHIC POLLUTION IN BULGARIA

KOMPLEKSOWA OCENA ZANIECZYSZCZENIA TROFICZNEGO TRANSGRANICZNEJ RZEKI MESTY W BUŁGARII

Abstract: A conceptual model for integrated river pollution assessment is proposed. Integral assessment of the trophic pollution of the transboundary Mesta River has been made for the initial (background) and final (reference) point of the Bulgarian section by means of some basic indicators. A time period characterizing the economic activity in the country during the transition to market economy has been considered for evaluation of the indicators.

The dynamics of the indicators: BOD₅, nitrates(V), nitrates(III), integral index for the trophic pollution level, average annual water amount and biotic index has been analyzed. The integral index is based on the organic and nutrients loading suspended and dissolved substances. Long-term trends seasonal patterns and data set structures are studied by the use of statistical analysis.

A trend towards reduction of the indicator values has been identified for background and reference point during the considered period (1989–1995). Only the nitrate(V) content in the background point exhibits a trend towards increasing the values due to natural processes in the catchment. On the basis of the retrospective analysis the conclusion can be drawn that the water quality needs the normative requirements of the river category in Bulgaria.

Keywords: quality assessment, water pollution, trend, integral indices

The European Framework Water Directive [1] requires an integrated approach to the water quality management that includes integration of water use and preserving of ecosystems, of quantity and quality of surface and groundwater, of the measures intended for management (action plan) on the basis of the physical and functional harmony of catchment elements.

The main objective of the integrated management is the sustainable utilization of water resources on the basis of the economic and social goals and the ecological requirements at water basin level.

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The European Water Directive demands “good quality” as a target for all water bodies within the range of the water basin. In the case of surface waters the “good status” is defined on the basis of physicochemical, hydrobiological and hydromorphological characteristics. The water quality indicators are parameters characterizing the type of pollution and its impact on the functioning of river ecosystems and water quality formation.

The basic water quality indicators are the indices for organic and nutrient pollution, the indices for pollution with harmful substances as the toxicity index, heavy metal content, petroproduct content, etc., the indices for the level of pollution, which are used for evaluating the effectiveness of water quality management. Some basic indicators have been applied for the assessment of the trophic pollution of the Mesta River.

The transboundary Mesta River flows in the western part of Bulgaria (Fig. 1).

The catchment area of the Bulgarian part of the river is 2768 km² with an average altitude of 1318 m. It is situated in a mountainous region, which is characterized by high



Fig. 1. Catchment area of Mesta River in Bulgarian section

degree of afforestations and 93 settlements with 135 000 inhabitants. The forests comprise 50 % of the catchment area [2]. Above the benchmark of 1100 m there is no anthropogenic activity in the Mesta River catchment that could exert negative impact on water quality, which is formed under natural conditions. Below the benchmark of 1100 m the water of the Mesta River is polluted by household and industrial wastewater from the settlements, agriculture, soil erosion and other sources.

The objective of the present work is to identify the tendencies in the dynamics of the basic indicators of organic and nutrient pollution (trophic pollution) in the beginning (background point) and in the end (reference point) of the Bulgarian section of the Mesta River.

The indicators are evaluated for a period, characterizing the economic activity in the country after the transition from the so-called totalitarian to market economy.

The dynamics of the indicators reflects the degree of the anthropogenic impact in the Mesta River catchment in the Bulgarian section.

Materials and methods

The present work considers the basic indicators for organic and nutrient pollution of the Mesta River water as BOD₅, nitrates and the integral index for the level of organic and nutrient pollution [3], the average annual water amount and the biotic index. The biological quality of the Mesta River at the background and the reference point has been determined on the basis of the biotic index information. The biological quality of water in Bulgaria is determined according to an Irish and a Bulgarian biotic index [4, 5].

A system of integral ecological indices has been worked out to assess the degree of pollution of running waters (Ip), sediments (Is) and rivers (Ir) [6].

The system of integrated indices for the level of river pollution is based on the ecological integrity of river flow [1]. Ecological integrity can only be achieved if physical, chemical and biological integrity simultaneously occur.

The integral index for the level of trophic pollution is based on the indices MES, BOD, COD, TOC, N_{tot}, P_{tot}, NO₃⁻, NO₂⁻, PO₄³⁻ and O₂ [7–9]. To assess the level of trophic pollution for a certain time period, it is necessary to determine the ratios between the actually measured values of the individual variables (C_i) and standard values (C_{i,0}) for a particular water body, or:

$$\gamma_i = C_i/C_{i,0} \quad (1)$$

The integral index for the level of trophic pollution for a certain period of time should be determined as the arithmetic mean of all measured values of individual parameters, or:

$$I_t = \frac{I}{n} \sum_{j=1}^n \sum_{i=1}^m \frac{C_{i,j}}{C_{i,0}} \quad (2)$$

m – number of indices,

n – number of determination for indicator parameters [6, 10, 11].

It is important for the targets of the water quality management system to follow the multi-annual dynamics of the average annual and maximal values of the mentioned indices. The assessment of water quality is based on information from three typical points – Yakoruda in the upper course, Momina Kula in the middle and Hadzhidimovo in the lower course of the river at a distance of 23 km from the border with Greece.

The water quality indicators are parameters characterizing the type of pollution and its impact on the functioning of river ecosystems and water quality formation.

Information from National System for Water Monitoring for a period 1990–2003 is analyzed. The information from the monitoring is standardized by help of Z-transformation.

The information about BOD₅ and the nitrates for determining the integral parameter of trophic pollution for the period 1989–2004 is analyzed. The tendency in the indicator dynamics is represented by a linear function of the type: $y = ax + b$.

The Statistica 5.5 software and Origin 6 has been applied for identifying the trend [12, 13]. The trend is used for evaluation of water quality in accordance with the requirements of the European Framework Water Directive.

Results and discussion

A) Background point Yakoruda

The multi-annual fluctuations of the average annual and maximal values of the BOD₅ indicator in the Yakoruda point for the respective years are shown in Fig. 2 and Fig. 3.

The trend in the dynamics of this indicator is represented by linear functions with high correlation coefficients $r = -0.74$ and $r = -0.63$, respectively.

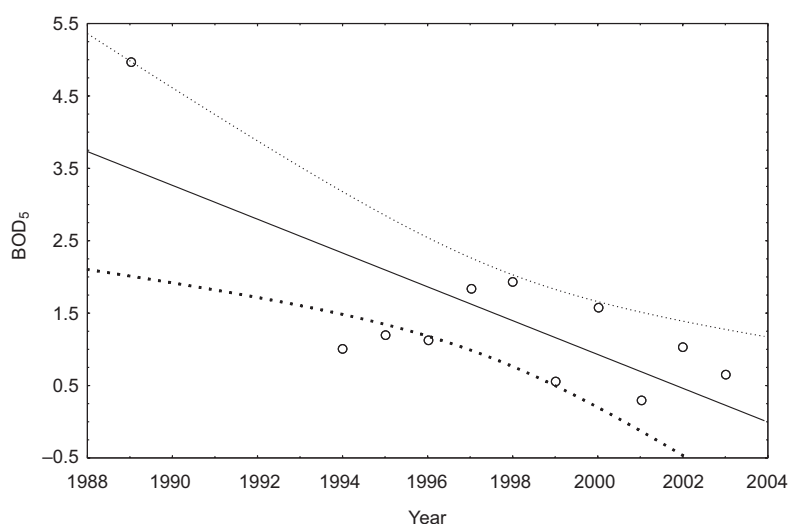


Fig. 2. Dynamics of the long-term values of the indicator – BOD₅ for the Mesta River at the Yakoruda point

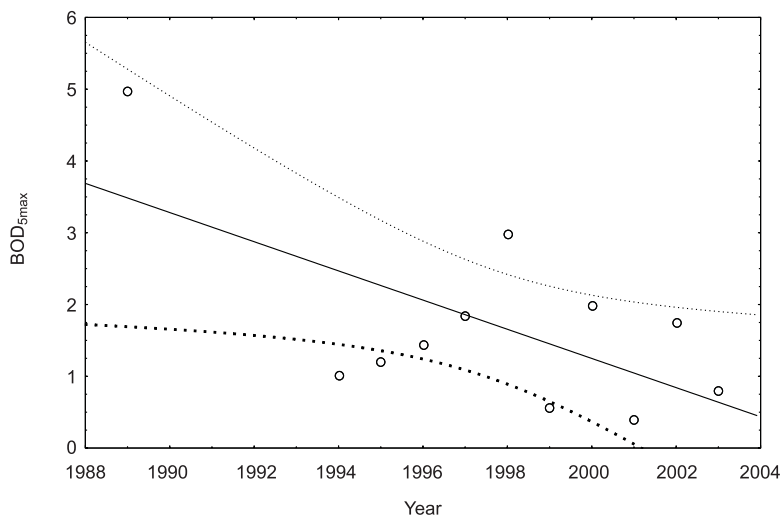


Fig. 3. Dynamics of the long-term values of the indicator – BOD_{5max} for the Mesta River at the Yakoruda point

A stable tendency towards decreasing the indicator values is observed for the considered period. The trend reflects the reduced organic pollution due to the decline of the economic activity in the region.

The multiannual fluctuations of the average annual and maximal values of the nitrates indicator and the trend for the considered period are shown in Fig. 4 and Fig. 5.

The trend is represented by linear functions with correlation coefficients $r = -0.69$ and $r = -0.74$, respectively. A tendency towards increasing the indicator values has been

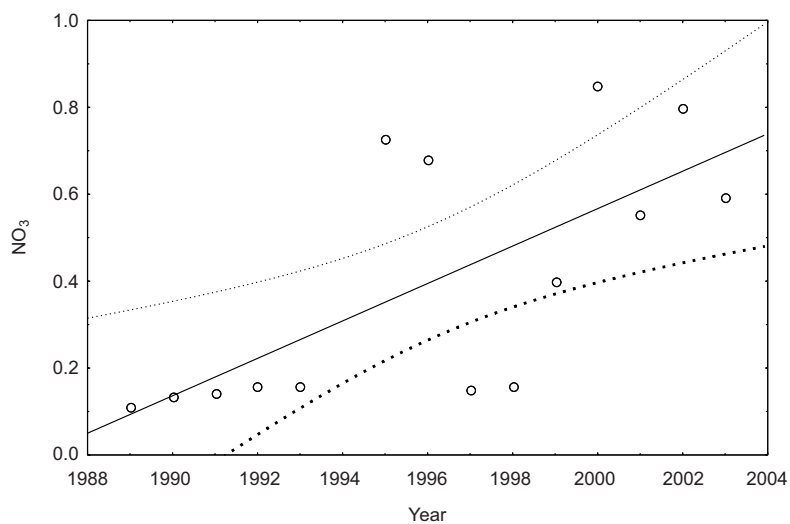


Fig. 4. Dynamics of the long-term values of the indicator – NO_3 for the Mesta River at the Yakoruda point

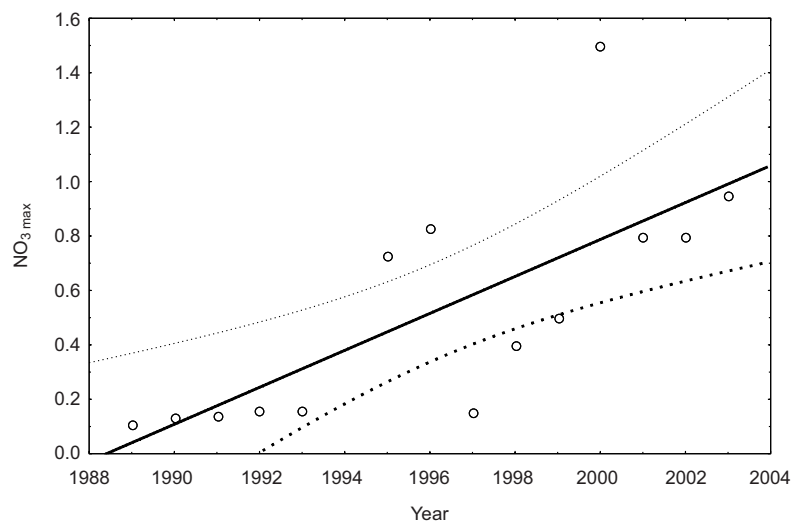


Fig. 5. Dynamics of the long-term values of the indicator – $\text{NO}_{3\text{max}}$ for the Mesta River at the Yakoruda point

established, which do not exceed the admissible norm. The nutrient pollution of the Mesta River water at the background point of Yakoruda is connected with natural processes occurring in the adjacent to the point catchment area.

The multi-annual fluctuations of the average annual values of the integral indicator for water trophic pollution and the trend for the considered period are shown in Fig. 6.

The data in Fig. 6 exhibit a slightly expressed tendency towards increasing of the I_t parameter values, which are significantly lower than unity.

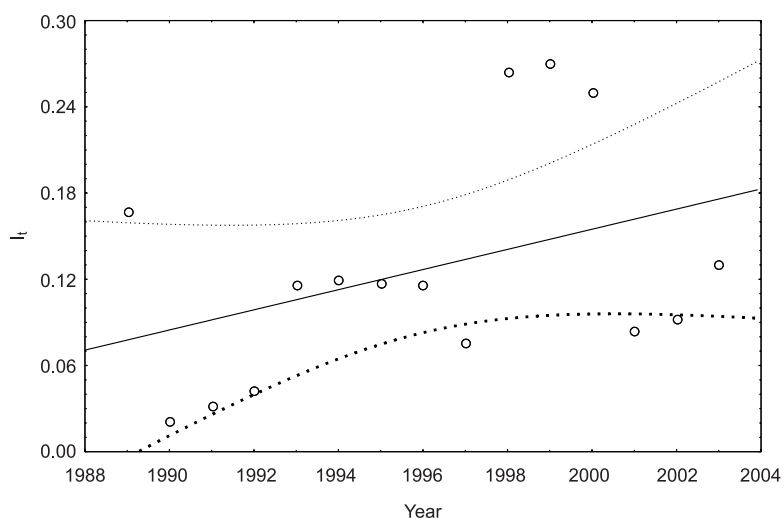


Fig. 6. Dynamics of the long-term values of the indicator – I_t for the Mesta River at the Yakoruda point

The analyzed information about the BOD_5 and nitrates indicators, as well as about the I_t parameter for the Yakoruda point provide the grounds to point out that the values of all trophic pollution indicators do not exceed the admissible norms ($\gamma_i < 1$).

The biotic index at the Yakoruda point for the period 1990–2004 shows values $BI = 4.5$, which is an indication of very good to excellent biological quality.

B) Reference point Momina Kula

In order to evaluate the distribution of pollution of the Mesta River from point and diffuse sources in the catchment area (Razlog, Bansko), a retrospective analysis was carried out of the information about the indicators I_t , phosphates, oxygen, nitrates and BOD_5 at the Momina Kula reference point.

The multi-annual fluctuations of the average annual and maximal values of the BOD_5 indicator for the respective years and the trend are shown in Fig. 7.

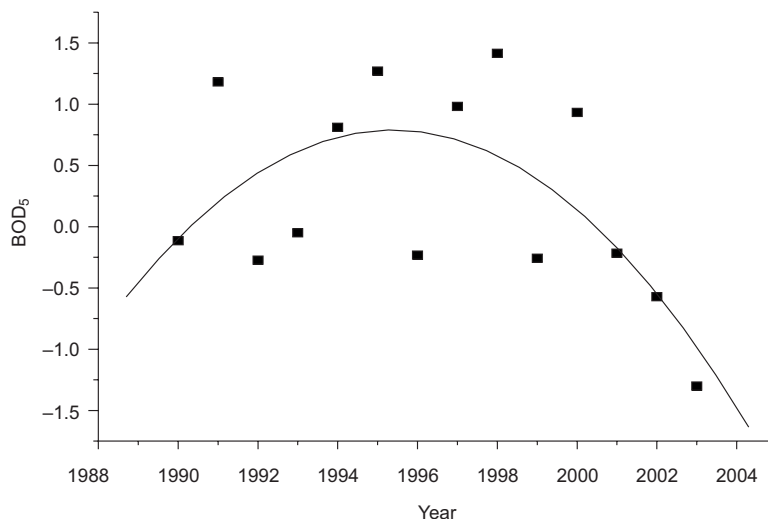


Fig. 7. Dynamics of the long-term values of the indicator – BOD_5 for the Mesta River at the Momina Kula point

The trend of the BOD_5 indicator is represented by a polynomial from second degree function with correlation coefficients – $r = 0.42$. A stable tendency towards decreasing the indicator values is observed for the considered period.

The multi-annual fluctuations of the average annual and maximal values of the nitrates indicator and the trend are shown in Fig. 8.

The linear function describing the trend in the dynamics of the average annual values exhibits a low correlation coefficient – $r = 0.11$. A slightly expressed tendency towards increasing the values of this indicator is observed for the considered period.

The multi-annual fluctuations of the average annual of the phosphates indicator and the trend for the considered period are shown in Fig. 9.

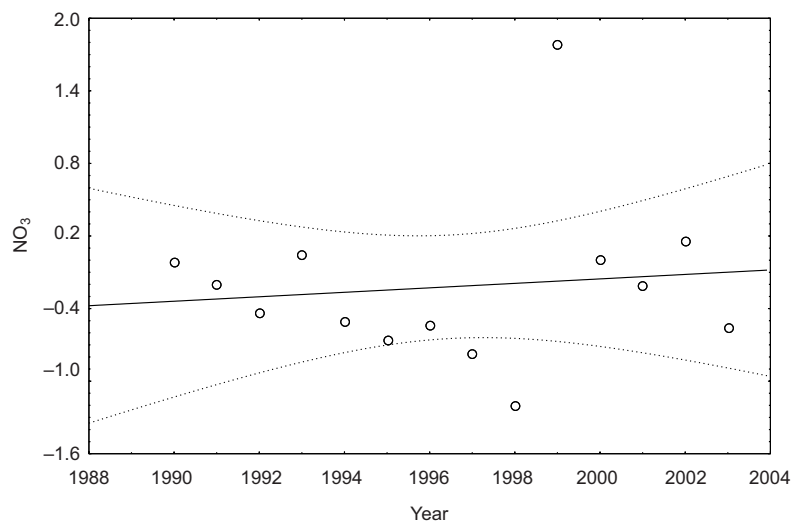


Fig. 8. Dynamics of the long-term values of the indicator – nitrates for the Mesta River at the Momina Kula point

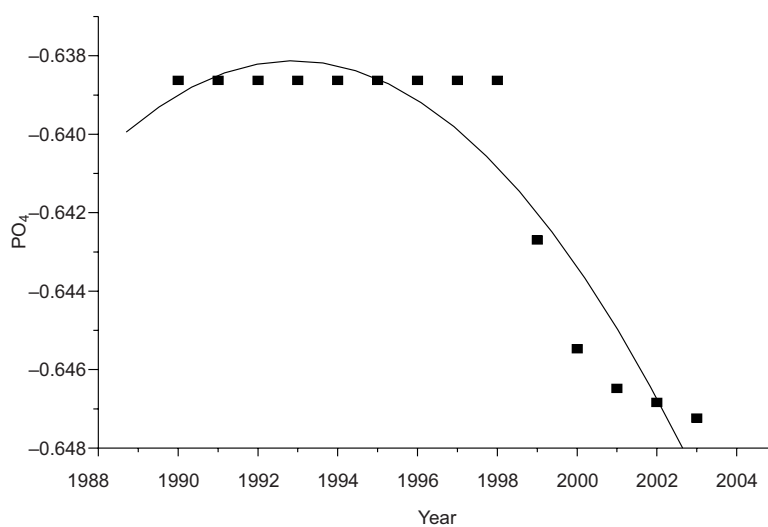


Fig. 9. Dynamics of the long-term values of the indicator – phosphates for the Mesta River at the Momina Kula point

The trend of the phosphates indicator is represented by a polynomial from second degree function with correlation coefficients $r = 0.90$. A stable trend towards decreasing the indicator values has been established. It can be used also a model for the phosphate dynamics.

The multi-annual fluctuations of the average annual of the oxygen indicator and the trend for the considered period are shown in Fig. 10.

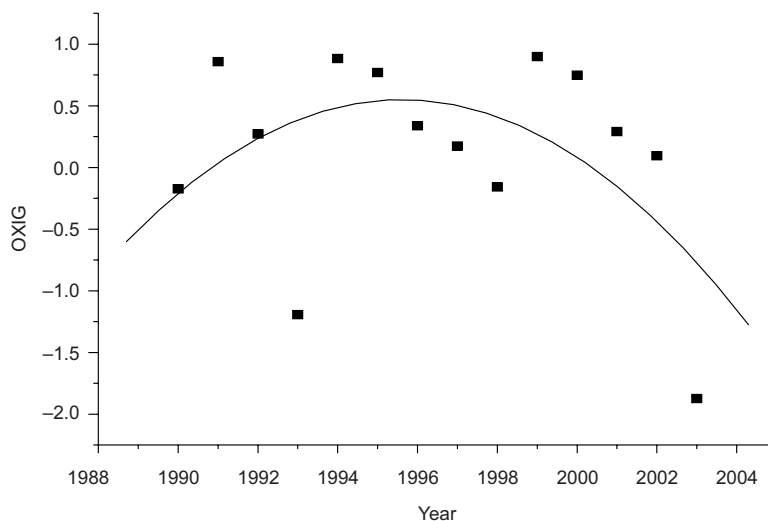


Fig. 10. Dynamics of the long-term values of the indicator – oxygen for the Mesta River at the Momina Kula point

The trend of the oxygen indicator is represented by a polynomial from second degree function with correlation coefficients $r = 0.25$. A significant tendency towards decreasing the indicator values has been established

The integral index of trophic pollution in this point (Fig. 11) displays a tendency towards decreasing the values for the regarded period. The correlation coefficient of a polynomial from second degree function describing the trend is $r = -0.73$.

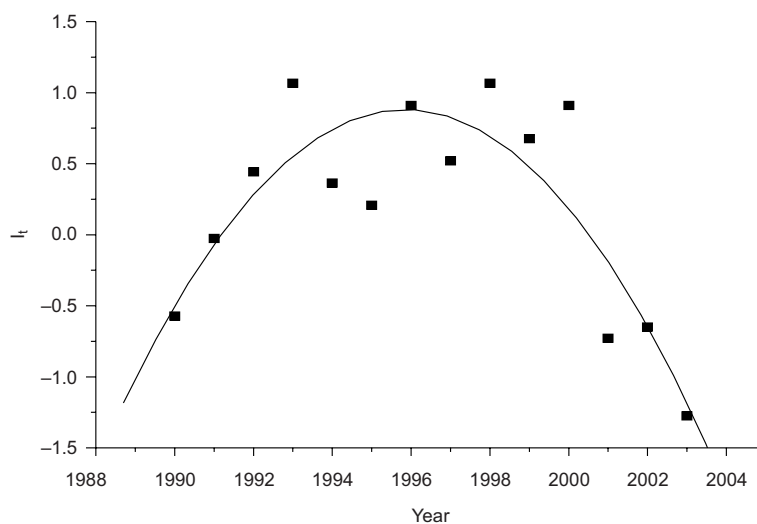


Fig. 11. Dynamics of the long-term values of the integral indicator for the Mesta River at the Momina Kula point

The trend in the dynamics of the maximal values exhibits stabilization of the results within certain range and do not exceed the admissible norm.

The analyzed information about the parameters BOD₅ and nitrates, phosphates, oxygen and for the integral index I_t, provides the grounds to point out that the values of all the trophic pollution indicators do not exceed the admissible norms ($\gamma_i < 1$) at this point.

The identified tendency towards reduction of the organic and nutrient pollution reflects the changes in the anthropogenic impact of the settlements and the industry in the considered region for the investigated period.

C) Reference point Hadzhidimovo

In order to evaluate the distribution of pollution of the Mesta River from point and diffuse sources in the catchment area, a retrospective analysis was carried out of the information about the indicators BOD₅ and nitrates at the Hadzhidimovo reference point.

The multi-annual fluctuations of the average annual and maximal values of the BOD₅ indicator for the respective years and the trend are shown in Fig. 12 and Fig. 13.

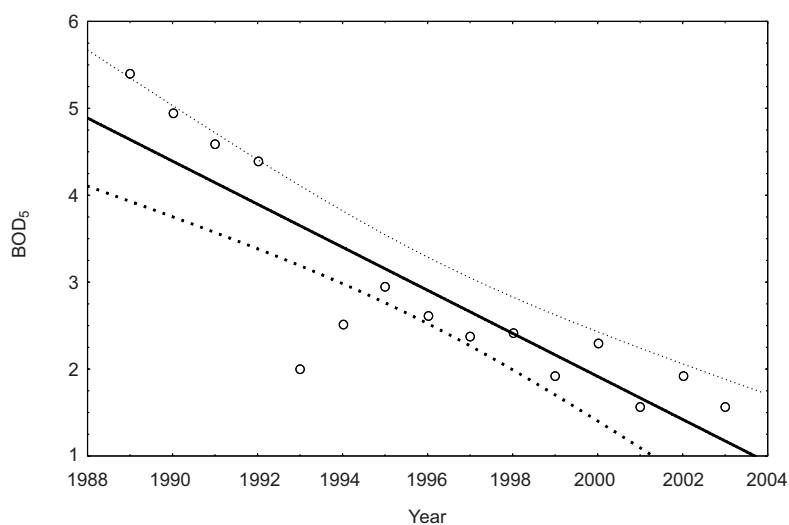


Fig. 12. Dynamics of the long-term values of the indicator – BOD₅ for the Mesta River at the Hadzhidimovo point

The trend of the BOD₅ and nitrates indicators is represented by linear functions with high correlation coefficients $r = -0.87$ and $r = -0.72$, respectively. A stable tendency towards decreasing the indicator values is observed for the considered period.

The reduced organic pollution in the reference point close to the border is related with the changes in the economic activity in the catchment area of the Bulgarian section of the river.

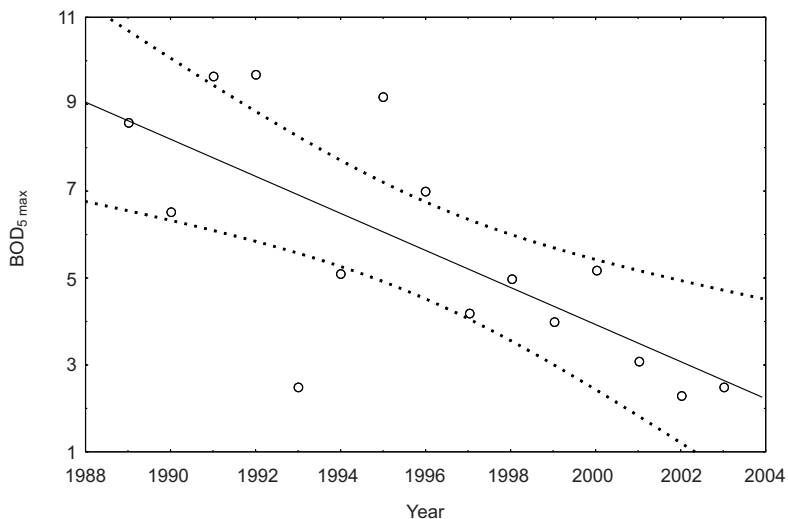


Fig. 13. Dynamics of the long-term values of the indicator – $BOD_{5\max}$ for the Mesta River at the Hadzhidimovo point

The multi-annual fluctuations of the average annual and maximal values of the nitrates indicator and the trend are shown in Fig. 14 and Fig. 15.

The linear function describing the trend in the dynamics of the average annual values exhibits a low correlation coefficient – $r = -0.27$. A slightly expressed tendency towards decreasing the values of this indicator is observed for the considered period.

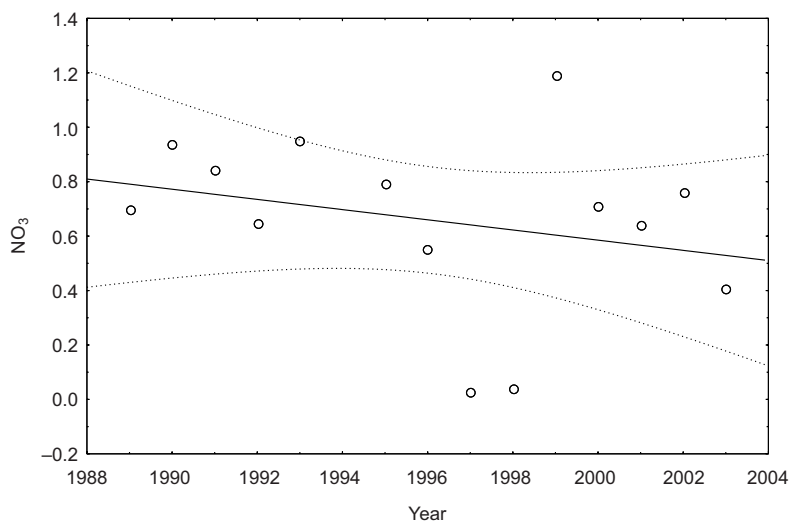


Fig. 14. Dynamics of the long-term values of the indicator – NO_3 for the Mesta River at the Hadzhidimovo point

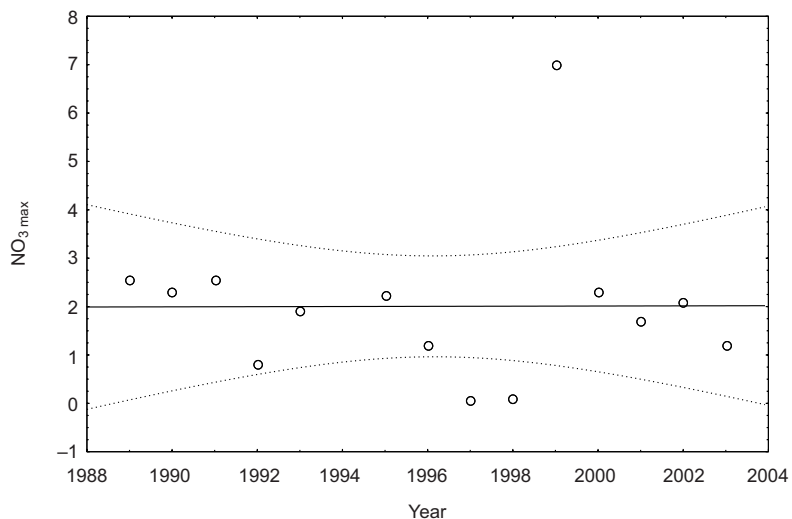


Fig. 15. Dynamics of the long-term values of the indicator – $\text{NO}_3 \text{ max}$ for the Mesta River at the Hadzhidimovo point

The trend in the dynamics of the maximal values exhibits stabilization of the results within a certain range and do not exceed the admissible norm.

The integral index of trophic pollution in this point (Fig. 16) displays a tendency towards decreasing the values for the regarded period. The correlation coefficient of the linear function describing the trend is $r = -0.48$.

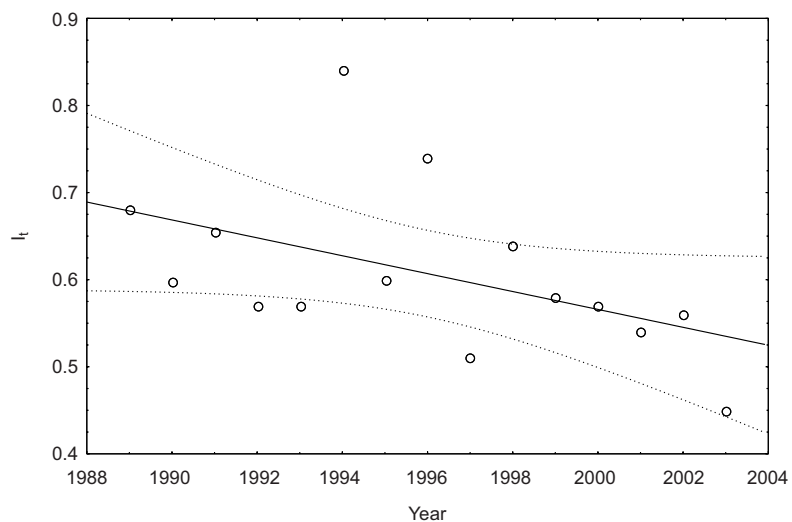


Fig. 16. Dynamics of the long-term values of the indicator – I_t for the Mesta River at the Hadzhidimovo point

The analyzed information about the parameters BOD₅ and nitrates, and for the integral index I_t , provides the grounds to point out that the values of all the trophic pollution indicators do not exceed the admissible norms ($\gamma_i < 1$) at the Hadzhidimovo point.

In accordance with the European Framework Water Directive of EU, a standard comparative assessment has been made of the values of the considered indicators at both points. For this purpose, the dynamics of the ratio between the average annual values of BOD₅ and nitrates at the Hadzhidimovo (C_i) and Yakoruda (C_0) points has been investigated for the considered period.

The dynamics of the $C_i / C_{i,0}$ ratio for the BOD₅ indicator is shown in Fig. 17.

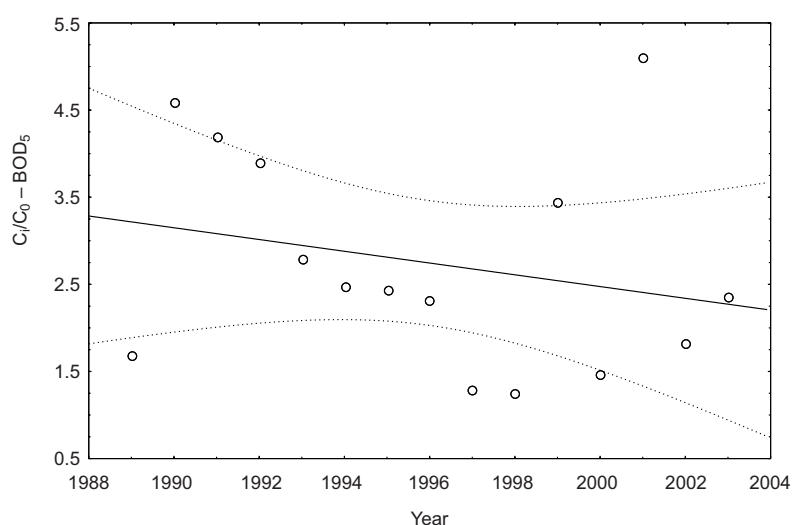


Fig. 17. Dynamics of the long-term values of the indicator – C_i/C_0 BOD₅ for the Mesta River at the Hadzhidimovo/Yakoruda points

A slightly expressed trend towards decreasing the values of this ratio is observed. The correlation coefficient of the linear function describing the trend is $r = -0.24$. The results show that the organic pollution of the river at the reference point exhibits a trend towards decreasing, ie the anthropogenic organic loading is becoming lower.

The multiannual fluctuations of the values of the ratio between the nitrates content in Hadzhidimovo and Yakoruda are shown in Fig. 18.

The linear function describing the trend has a correlation coefficient $r = -0.82$, ie the trend is stable. The data reveal a stable trend towards decreasing of the $C_i / C_{i,0}$ values for the considered period.

The identified tendency towards reduction of the organic and nutrient pollution reflects the changes in the anthropogenic impact of the settlements and the industry in the considered region for the investigated period.

The biotic index at the reference point of Hadzhidimovo for the period 1990–2004 exhibits values of 3.0–3.5, which is an indication of very good, acceptable biological

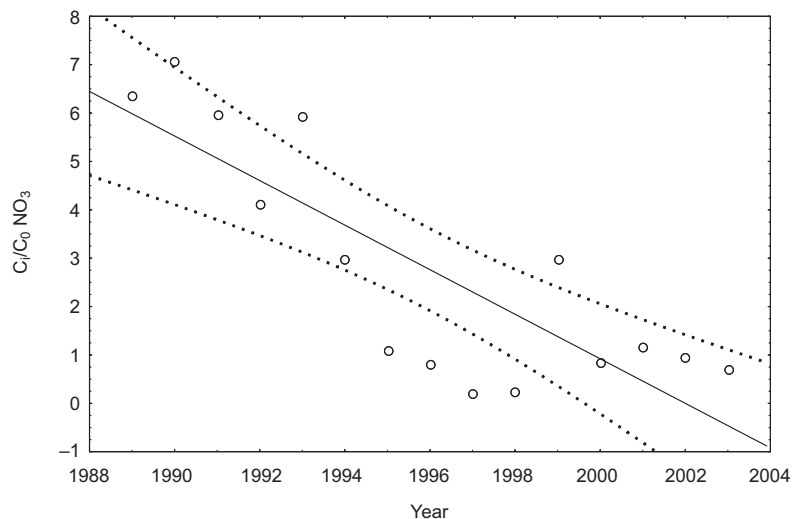


Fig. 18. Dynamics of the long-term values of the indicator – $C_t/C_0 \text{ NO}_3$ for the Mesta River at the Hadzhidimovo/Yakoruda points

quality. As a result of the tendency towards reduced organic and nutrient pollution of the Mesta River water at the Hadzhidimovo point, improvement of the biological water quality may be expected at this point.

River runoff represents a basic indicator for surface water quality formation [14–17]. The dynamics of the average annual values of the river runoff for a period longer than 30 years is an important parameter for the formation of the qualitative and quantitative surface water characteristics [18, 19]. A retrospective analysis of the average annual water amount fluctuations in the considered points has been made in the present work. The dynamics of the average annual water amounts in Yakoruda and Hadzhidimovo is shown in Fig. 19 and Fig. 20.

The linear function describing the trend in Yakoruda has a correlation coefficient $r = -0.74$, and in Hadzhidimovo – $r = -0.70$. A stable trend towards decreasing the average annual runoff values is observed for the considered period in both points. The investigations carried out identify a stable tendency in the dynamics of the river runoff formation processes in the catchment area of the Bulgarian section of the Mesta River.

On the basis of the retrospective analysis of the water quality indicators, the conclusion may be drawn that a tendency towards decreasing their values has been identified at the background and at the reference point for the studied period. Only the nitrates content at the background point exhibits the tendency of increasing values, obviously originating from natural processes in the catchment.

This positive result for the Mesta River water quality is due to the strongly reduced economic activity of the population in the catchment area after 1989. The recovery of the economic activity is an inevitable necessity for the development of the region and hence measures have to be envisaged for preserving water quality on both regional and transboundary level.

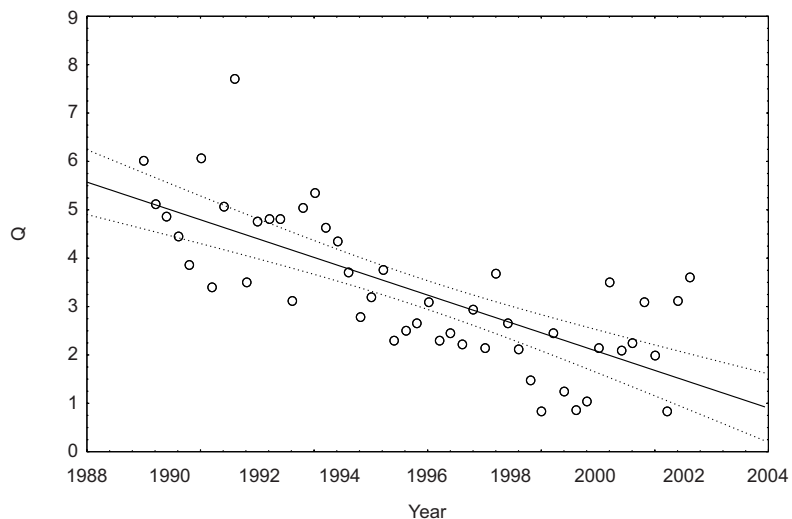


Fig. 19. Dynamics of the long-term values of the indicator – Q for the Mesta River at the Yakoruda point

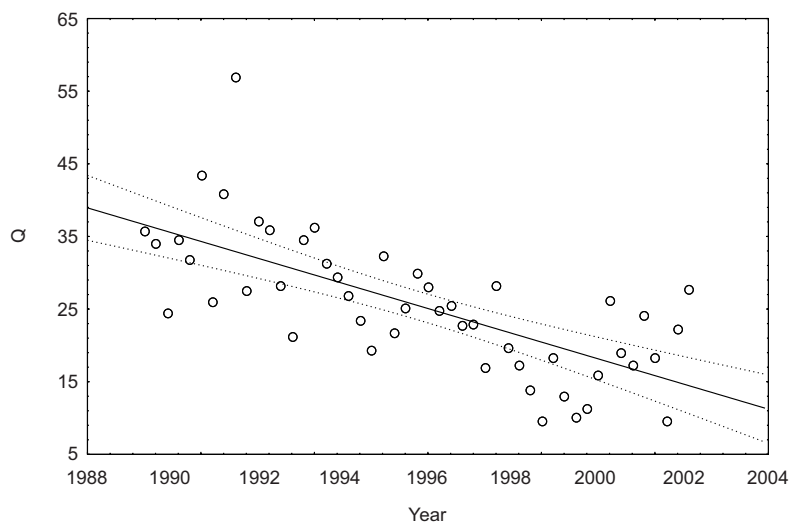


Fig. 20. Dynamics of the long-term values of the indicator – Q for the Mesta River at the Hadzhidimovo point

Conclusions

On the basis of the analysis of the nutrient pollution of the Mesta River at the three typical points, the conclusion can be drawn that the capacity of the self-purification processes of the river has not been disturbed and the water quality meets the normative requirements for the river category in Bulgaria.

The values of the water quality indicators at the background point show the influence of natural conditions on the water quality formation in the region. The chosen water quality indicators reflect adequately the anthropogenic impact intensity in the catchment for the considered period. The integral index for the level of trophic water pollution is an instrument of river water quality management. The trend in the dynamics of this index gives an opportunity for evaluating the efficiency of the water management strategy.

The organic and nutrient pollution of the Mesta River in the Bulgarian section does not result in any negative trends to aggravating the river water quality. The water trophic pollution meets the requirements of the Bulgarian standards. The water quality of the Mesta River in the end of the Bulgarian section is improved according to the investigated indicators for the studied period, which reflects the decline in the economic activity after the changes in 1990.

Acknowledgement

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KOMPLEKSOWA OCENA ZANIECZYSZCZENIA TROFICZNEGO TRANSGRANICZNEJ RZEKI MESTY W BUŁGARI

Abstrakt: Zaproponowano koncepcję modelu zintegrowanej oceny zanieczyszczenia rzeki. Dokonano całościowej oceny troficznego zanieczyszczenia transgranicznej rzeki Mesty na podstawie wartości podstawowych

wskaźników zmierzonych w początkowym (tła) i końcowym (referencyjnym) bułgarskim odcinku rzeki. Dokonując ocen wskaźników, uwzględniono zmiany gospodarcze zachodzące w kraju, w tym przejście do gospodarki rynkowej. Analizowano wartości takich wskaźników, jak: BZT₅, stężenie azotanów(V), stężenie azotanów(III), całkowity wskaźnik zanieczyszczeń troficznych, średni roczny przepływ wody i wartości indeksu biotycznego. Całkowity wskaźnik uwzględnia ładunek organicznych i zawieszonych składników pokarmowych oraz substancje rozpuszczone. Dokonano analizy statystycznej długoterminowych trendów sezonowych i struktury rozpatrywanych zbiorów danych. W badanym okresie (1989–1995) zaobserwowano tendencję w kierunku zmniejszenia się wartości wskaźników w punkcie tła i punkcie odniesienia. Tylko azotany(V) w punkcie tła w zlewni wykazują tendencję do wzrostu wartości w wyniku naturalnych procesów. Na podstawie analizy retrospektywnej można stwierdzić, że jakość wody mieści się w normatywnych wymogach dla rzek w Bułgarii.

Słowa kluczowe: oceny jakości, zanieczyszczenia wód, tendencja, wskaźniki całkowity