IMPACT OF CLIMATE CHANGE ON THE WATER QUALITY OF THE DANUBE RIVER LOWER SECTOR

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Abstract: Impact of climate change on the water quality of the danube river lower sector. The paper highlights the effects of climate change on water quality of the Danube River lower sector. The impact of climate change on the water quality of the lower Danube sector was assessed by analysing the multiannual variation of the oxygen and nutrient parameters concentrations and the correlation with the water temperature for the period 1996-2014. From the physico-chemical point of view, the parameters studied are: water temperature, dissolved oxygen, biochemical oxygen demand (BOD_5), nitrates, ammonium, nitrites and orthophosphates. This multiannual variation was also analysed at the level of the 12 months (January-December), corresponding to the studied period. Based on the monthly multiannual trends highlighted for water temperature, their effect on the parameters of the oxygen and nutrients regime has been studied and has been interpreted taking into account the processes of the oxygen, carbon, nitrogen and phosphorus cycles, respectively the oxidation of biodegradable organic compounds, nitrification-denitrification processes and phytoplankton production. From the perspective of the hydrological regime, the variation of the oxygen and nutrient parameters with the extreme hydrological regime for the years 2003 and 2006 was evaluated.

Key-words: climate change, water temperature, hydrological regime, quality parameters, analysis, temporal trend.

1. INTRODUCTION

Changes in the hydrological cycle produced by global warming can have socio-economic and environmental effects due to the occurrence and duration of extreme events such as floods and droughts, with changes in water availability and water quality. Climate change impacts the physical, chemical and biological characteristics of aquatic ecosystems, due to changes in hydrological regime and air temperature and, implicitly, water temperature.

From the point of view of the hydrological regime, climate change is predicted to alter availability, seasonal variation and flow variability. Increased run off and discharges from the basin and river flows may lead to increases in dissolved oxygen, nitrate and ammonium concentrations, but also to decreases in orthophosphates concentrations due to dilution (Hosseini, Water, 2017).

The variation of water temperature is affecting physico-chemical, biological and microbiological processes. From a physicochemical point of view, natural processes are affected, especially nitrification-denitrification, mineralization of

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organic matter with changes in the concentrations and loads of pollutants transported by the rivers. Studies show that higher water temperatures and reduced flow rates in summer lead to decreased dissolved oxygen concentrations and increased concentrations of biodegradable organic matter (measured as biochemical oxygen demand - BOD_5) and phosphorus leading to affecting the trophic status. Consumption of ortho-phosphates in the algal growth process leads to a decrease in their concentrations. Also, ammonium concentrations decrease due to increased nitrification rate, increasing the concentration of nitrates, which are used during the summer in the algal growth process (Hosseini, N, Water, 2017).

The results of the Prairie River study in Canada, using the mathematical models, showed that the impact of climate change on water quality, respective the increasing water temperature, materialize by reducing dissolved oxygen concentrations and decreasing nutrient concentrations, with the highest decreases occurring late summer and autumn (August and September) due to phytoplankton development. In situations of extremely high hydrological regime, concentrations of dissolved oxygen, but also of nitrogen and ammonium, have increased. In deep reservoirs, rising water temperatures and increased oxygen demand (anoxic conditions) can lead to the remobilization of nutrients from sediments.

In the **Danube River Basin**, the Climate Change Adaptation study done by Ludwig Maximilians University Munich - Germany (Danube Study - Climate Change Adaptation), as well as the Technical Reports of the Joint Research Center - Water Scenarios for the Danube River Basin (JRC Technical Reports, 2016) have highlighted that air temperature will increase in the Danube River Basin by a gradient from NW to SE (2030 - 2050), with more than 1 ° C in the E and SE of the river basin (JRC, 2016). As for Romania, the summer temperature will increase by 1.8-2.1 ° C and by 1.4-1.5 ° C in winter for the period 2021-2050 (Danube River Basin Study on Climate Change Adaptation, 2012).

In terms of rainfall, annual average rainfall is expected to follow a decreasing trend, but with seasonal rainfall, drop in summer rainfall (25% - 45%) and mild increase or stability during winter. Thus, it is forecast that the annual average rainfall values will decrease by 5% to 15% in Romania. At the same time, the duration snowfalls period will decrease (except in the mountain area), with early and rapid melting conditions of snow (Danube River Basin Study on Climate Change Adaptation, 2012).

For the lower basin of the Danube River, longer periods with higher temperatures, a high humidity deficit, tropical nights (increase by 0.4-1 day / decade), declining frost days number (-3 days / decade) are predictable, respectively extreme precipitation. Also, the conditions for ice formation on the Danube River and its tributaries will be more reduced (Danube River Basin Study on Climate Change Adaptation, 2012).

The maximum number of consecutive days without precipitation will increase on average from 25 days to almost 40 days for the above mentioned period, practically translating through intense and extended periods of drought and increasing the frequency of droughts with decreasing water content in soil, as well as hydrological droughts, respectively reduced flows (JRC, 2016).

The annual average discharge of the Danube's lower basin will decrease by 5-20%, due to its excessive decrease during the summer. Also, potential evaporation will increase, and annual average evapotranspiration will decrease, particularly in the summer (Danube River Basin Study on Climate Change Adaptation, 2012).

It is also possible to increase the flood risk and the frequency of floods, especially flash floods, but will reduce the risk of early spring floods due to low snow cover (Danube River Basin Study on Climate Change Adaptation, 2012).

An increase of water temperature is predictable due to the increase of air temperature, continuing the trend observed last century when water temperature in Europe's rivers increased by 1 K. Thus, the winter and seasonal transition seasons are the most affected. Increasing water temperature causes changes in chemical and biological processes by lowering the oxygen content in water impacting on ecosystems and aquatic biodiversity (Danube River Basin Study on Climate Change Adaptation, 2012).

The Danube River quality can be affected by seasonal changes, more frequent extreme flood and drought phenomena and rising water temperatures, making it more vulnerable to pollution. Increased temperatures will also lead to lower dissolved oxygen content (due to decreased oxygen solubility in water and increased biological oxygen consumption rate) as well as an impact on the intensity and duration of eutrophication phenomena (algal growth). At the same time, it will increase the rate of mineralization of nitrogen, phosphorus and carbon, due to the heating of water. Frequent floods and flash floods will result in anoxic conditions, greater mobility of pollutants adsorbed to suspended solids (heavy metals, persistent organic pollutants), and changes in the redox equilibrium of inorganic compounds due to the release of organic colloids. During low waters, after prolonged drought, discharges from point pollution sources can have a greater impact due to reduced dilution. In reservoirs, the re-suspension of bottom sediments leads to increased phosphorus concentrations, and due to longer algal growth periods, nutrient concentrations will decrease, and nitrogen concentrations will decrease due to denitrification processes (Danube River Basin Study on Climate Change Adaptation, 2012).

In Romania, in the frame of research study (ADER) - Geo-referential indicators system at different spatial and temporal scales for assessing vulnerability and the adaptation measures of agroecosystems to global changes (2011-2014), the National Meteorological Administration (ANM) performed climate scenarios for the 21st century and estimated the effects on the multiannual average air temperature as well as on the multiannual average precipitation in Romania.
Thus, an increase in the average annual air temperature compared with the 1980-1990 period is estimated, similar to the whole Europe, depending on the scenario, there were small differences between the results of the models for the first decades

of the 21st century and the higher for the end of the century, 0.5 ° C and 1.5 ° C for the period 2020-2029 and between 2.0 ° C and 5.0 ° C for 2090-2099.

Regarding the precipitation regime, for the period 1901-2010, the analyses indicate the existence, especially after 1961, of a generally decreasing trend of the annual quantities of rainfall in the whole country, as well as a sharp increase of the rainfall deficit in the areas from S and E of Romania. Thus, there are estimated increases in air temperatures, changes in precipitation regime, extreme events and natural disasters.

2. DATA AND METHODS

In this context, the research aimed at highlighting the effects of climate change on water quality in a representative monitoring site on the lower sector of the Danube River, namely Reni section (located at km 132) within the Transnational Monitoring Network (TNMN) of the International Commission for the Protection of the Danube River (ICPDR). For this analysis, only the concentrations in the middle profile of the Reni monitoring site were used, as it is less affected by wastewater discharges from both river banks.

From the physico-chemical point of view, the parameters studied are: water temperature, dissolved oxygen, biochemical oxygen demand (BOD_5), nitrates, ammonium, nitrites and orthophosphates. Thus, variations in the dissolved oxygen, BOD_5, nitrate, ammonium, nitrite and orthophosphate concentrations with varying water temperatures for the period 1996-2014 were studied. These parameters are bimonthly monitored in the Reni monitoring site in the frame of TNMN.

This multiannual variation was also analysed at the monthly level (January-December), corresponding to the studied period (1996-2014).

From the point of view of the hydrological regime, the variation of the oxygen and nutrient regime parameters with the average monthly flow rate for the years 2003 and 2006 was evaluated in the qualitative monitoring site Reni, respectively in the Isaccea gauging station (km 100.2). It is noted that the distance between the Reni qualitative monitoring section and the Isaccea gauging station is relatively small (31.8 km), between then being no significant external flow contribution. The two years have been selected because they are different from the hydrological point of view for the lower sector of the Danube River: 2003 is characterized by low monthly average flows in the second part of the year, and 2006 is characterised by very high monthly average flows over the months March to June.

Isaccea station is measured by several daily determinations from which the average, minimum and maximum daily, monthly, annual and multiannual average flows are calculated.

3. RESULTS AND DISCUSSIONS

3.1. Analysis of the multiannual variation of physico-chemical parameters with water temperature

The hydrological regime and water temperature govern the physico-chemical processes in the aquatic environment. Both the hydrological regime and the water temperature, but especially their seasonal variability, are influenced by global warming. As mentioned above, the correlation / dependency of water temperature variation with variations in dissolved oxygen, BOD_5, nitrate, ammonium, nitrite and orthophosphate concentrations during the analysed period was studied.

The *water temperature* variation analysis shows that the minimum recorded value is 0.1 ° C (recorded in January 2002 and 2003) and the maximum value is 28 ° C (recorded in July 1996). The average multiannual average for the analysed period is 14,3 ° C, with a stable temporal trend, noting a general trend of water heating for the analysed period.

From the analysis of the variation of *dissolved oxygen* concentrations it can be noted that they vary in the range of 5.12-14.45 mg O_2 / l, the minimum value being recorded in August 2002 (at water temperature of 21°C) and the maximum value was recorded in February 2006 (at water temperature of 2.5 ° C) (Figure 1).

From the point of view of the multiannual average value, it has been calculated and has a value of 9.25 mg O_2 / l and the dissolved oxygen concentration values have a clear upward trend showing the improvement of the water quality. Also, Figure 1 shows, as is normal, a good correlation between the dissolved oxygen concentrations and the water temperature, respectively, as the water temperature is lower, the higher the oxygen concentration.

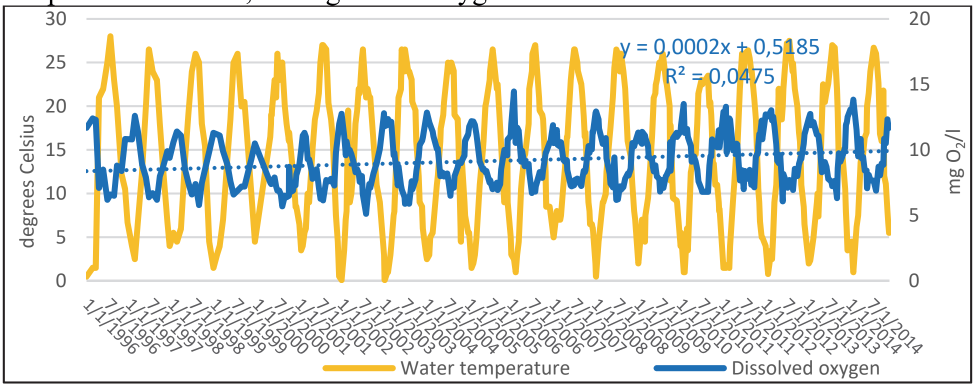

Figure 1. Variation of the dissolved oxygen concentration with the water temperature in the Reni monitoring site

Regarding the concentrations of *biodegradable organic substances measured by BOD_5*, the analysis shows that the variation range is 6.2 mg O_2 / l (recording values between 0.2 - 6.4 mg O2 / l), the minimum being recorded in the month October 2008 (at a water temperature of 15.5 ° C), and the maximum value was measured in June 1997 (at a water temperature of 26.5 ° C). The average multiannual value for the analysed period is 1.99 mg O2 / l, with a decreasing trend over time (Figure 2).

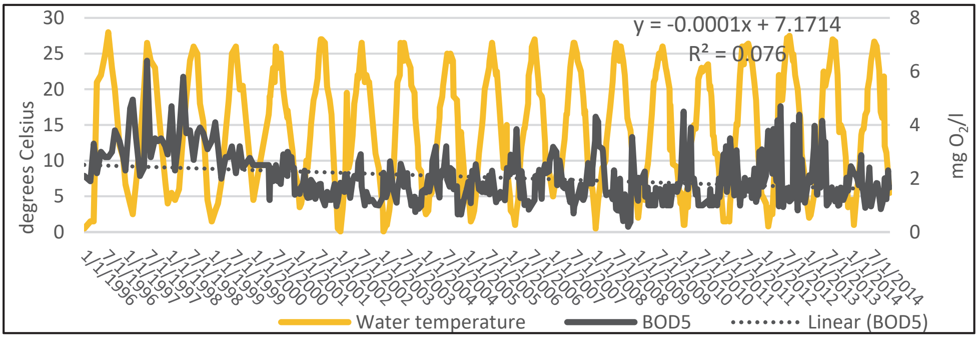

Figure 2. Variation of the BOD5 concentration with the water temperature in the Reni monitoring site

This graph highlights a tendency to improve water quality from the point of view of biodegradable organic matter over the period under consideration, explaining the increasing trend of oxygen concentrations. Practically, there is less consumption of dissolved oxygen used for water self-purification.

As regards the variation in the concentrations of the nitrogen parameters, they have decreasing trends from temporal point of view, due to the reduction of emissions from point and diffuse pollution sources (Figures 3, 4 and 5).

The *N-nitrates concentrations* were in the range of 0.01 - 3.46 mg N-NO3 / l, the multiannual average being 1.55 mg N-NO3 / l, the minimum being recorded in January 2011, and maximum in March 2006 (at a flow rate of 10000 m^3/s at the Isaccea gauging station). For *N-ammonium* the measured concentrations varied between 0.02 mg N-NH4 / l (January 2004 and February 2005) and 1.53 mg N-NH4 / l (January 1998) and the multiannual mean value was 0, 24 mg N-NH4 / l.

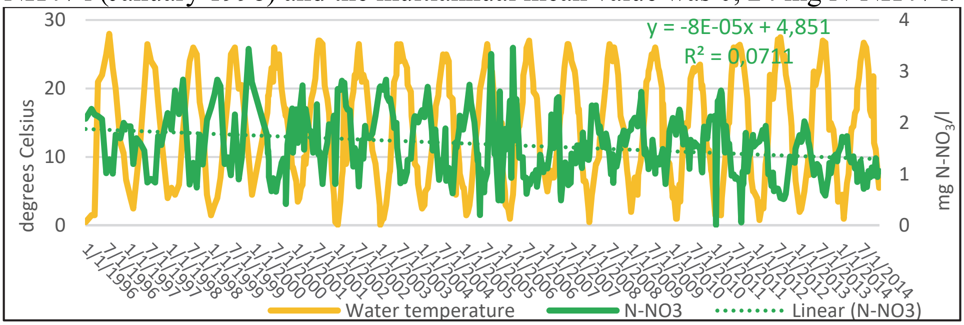

Figure 3. Variation of the N-Nitrates concentrations with the water temperature in the Reni monitoring site

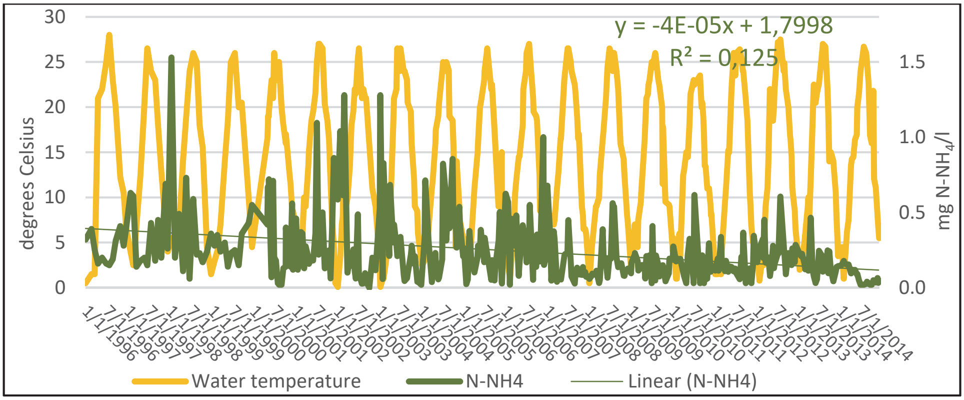

Figure 4. Variation of the N-Ammonium concentrations with the water temperature in the Reni monitoring site

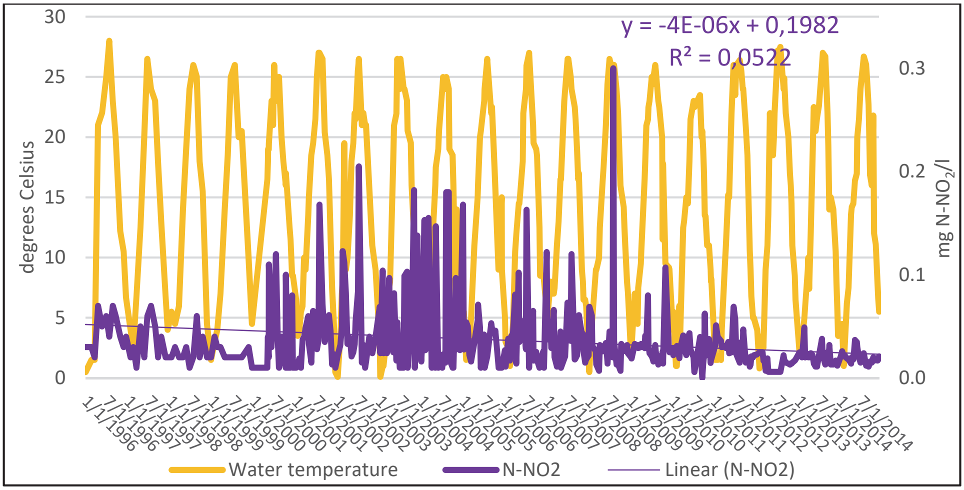

Figure 5. Variation of the N-Nitrites concentrations with the water temperature in the Reni monitoring site

Concentrations of measured *P-orthophosphates* ranged from 0.01 mg P-PO4 / l (recorded in October to December 2003) and 0.37 mg P-PO4 / l (recorded in December 2006), with a multiannual average of 0 , 04 mg P-PO4 / l and an increasing trend in time (Figure 6).

The analysis of the multiannual variation of physico-chemical parameters (water temperature regime, oxygenation conditions and nutrient regime) for the period 1996-2014 shows an increasing temporal trend for dissolved oxygen and orthophosphates and a decreasing trend for biodegradable oxygen demand and inorganic compounds of nitrogen, while the water temperature has a quasi-stable trend. At the same time, an inverse variation between water temperature and dissolved oxygen concentrations was highlighted.

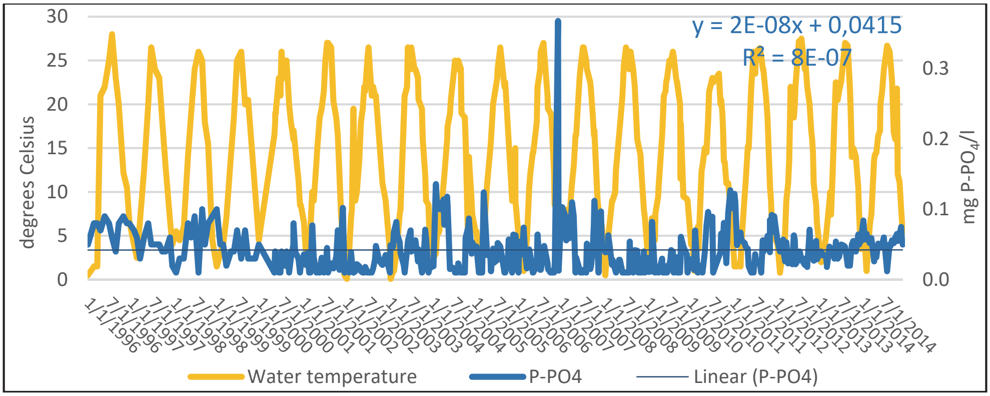

Figure 6. Variation of the P-ortophosphates concentrations with the water temperature in the Reni monitoring site

3.2. Analysis of monthly multiannual variations of the physico-chemical parameters concentrations with water temperature

For a more detailed analysis of the possible impact of global warming on the temporal and seasonal variation of physico-chemical parameters concentrations, this variation and the correlation between the parameters for each month (January-December) for the period 1996-2014 in the Reni monitoring site have been studied (Table 1).

Table 1. Multiannual linear trend of monthly concentrations of physico-chemical parameters in the Reni monitoring site

Month	**Multiannual linear trend of monthly values**						
	Water temperature	O_2	BOD_5	$N\text{-}NO_3$	$N\text{-}NH_4$	$N\text{-}NO_2$	$P\text{-}PO_4$
January	↓	↑	↑	↓	↑	↓	↓
February	↓	↑	↓	↓	↓	↑	↓
March	↓	↑	↓	↑	↑	↑	↑
April	↓	↑	↓	↓	↑	↑	↑
May	↓	↑	↑	↓	↑	↓	↓
June	↓	↑	↑	↓	↑	↑	↓
July	↓	↑	↑	↑	↓	↓	↓
August	↑	↑	↑	↑	↓	↓	↓
September	↑	↑	↓	↑	↑	↑	↑
October	↑	↑	↑	↓	↑	↓	↓
November	↑	↑	↑	↑	↓	↑	↑
December	↑	↑	↑	↓	↓	↓	↑

The graphs of multiannual variation of water temperature and dissolved oxygen concentration for 12 months in the Reni site for the studied period were analysed. Also, as examples, the figures 7-10 show the multiannual variation corresponding to January, April, August and November.

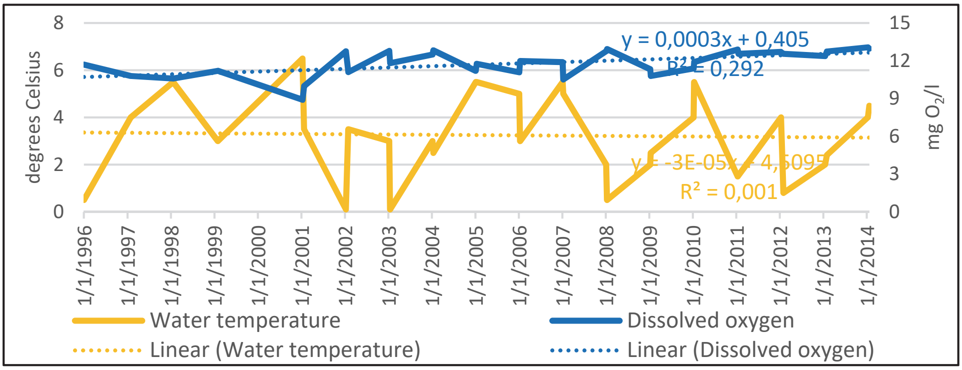

Figure 7. Multiannual variation in water temperature and dissolved oxygen concentration in January in the Reni monitoring site

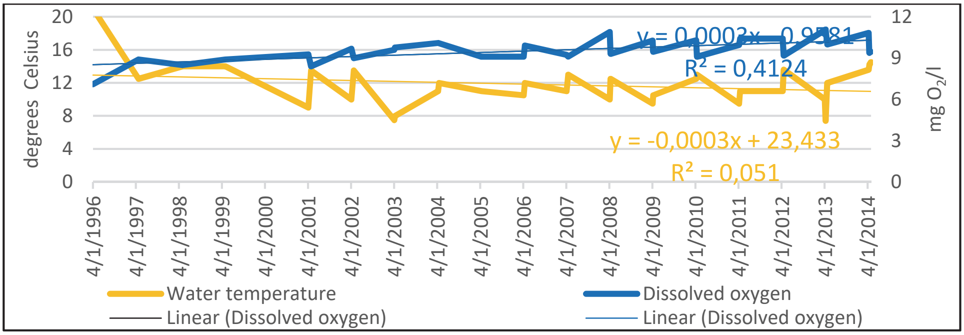

Figure 8. Multiannual variation in water temperature and dissolved oxygen concentration in April in the Reni monitoring site

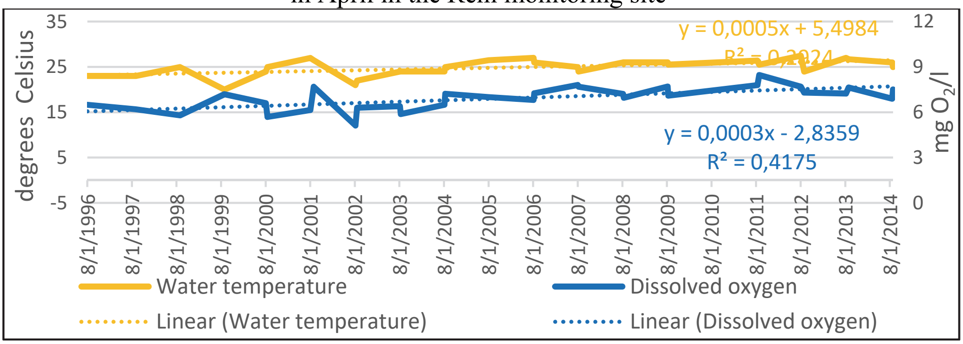

Figure 9. Multiannual variation in water temperature and dissolved oxygen concentration in August in the Reni monitoring site

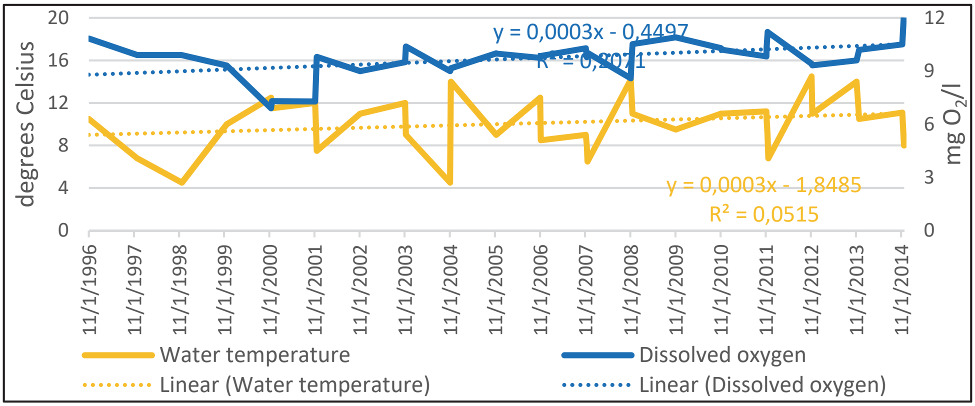

Figure 10. Multiannual variation in water temperature and dissolved oxygen concentration in November in the Reni monitoring site

With regard to water temperature, there is a decreasing trend for January-July and an increasing one for the months of August-December, which shows a possible effect of global warming on water temperature.

Concerning the *monthly multiannual variation of the dissolved oxygen concentration*, there is an increasing trend which shows rather a more important effect of reducing the intensity of pollution with organic matter in the Danube River Basin that exceeds the possible impact of the increase of the water temperature corresponding to the months of August - December.

The *multiannual variation in monthly biodegradable organic demand (BOD_5)* values shows an increasing trend for most of the months, except for the months of February - April and September that have a downward trend. The decrease in the months of February - April can be explained by increasing the flow and the dilution of the quantities of organic matter in the large volume of water.

From a temporal point of view, *nitrogen from nitrates concentrations* show a multiannual decreasing trend for the winter months, April - June, October and December and upward for March, July - September and November. The increasing trend in March and November is explained by diffuse nitrogen emissions that reach the Danube River through runoff and surface leakages from agricultural land or polluted soils. Also, the temporally increasing values in July-September may be caused by the decrease of the flow rate and the concentration of nitrogen in the mass of water. Also in these months, ammonium concentrations decrease, indicating a nitrification process that exceeds the nitrate consumption needed for phytoplankton growing.

Regarding the variation of the *multiannual monthly N-ammonium concentrations*, it is observed that there is an upward trend for the first 6 months (except for February) that correlates with the soils washing processes of the ammonium compounds (natural and chemical fertilizers) having place in the spring - summer beginning, as well as a correlation with the temperature variation of the water with decreasing trend that does not favour the nitrification processes. Conversely, in the months with decreasing trend of N-ammonium concentrations, respectively July-August and November-December, shows a possible concentration of dissolved substances related to the reduced flows during the summer period, as well as the effect of the increase of the water temperature in November-December of the analysed period which leads to an increase in the rate of nitrification.

N-nitrite concentrations vary at monthly multiannual levels similar to concentrations of N-ammonium. Except for February, May, October and November, these concentrations generally have an increasing multiannual trend over the first 6 months and a downward trend over the last 6 months of the year, correlating well with water temperature trends (rising water temperatures catalyses the processes of nitrification / transformation of nitrites into nitrates).

With regard to the *monthly multiannual variation in phosphorus concentration* in orthophosphates, a decreasing trend is observed for most months, especially the warmer months (May-August), which shows the consumption of orthophosphates in algal growth (production of phytoplankton). A multiannual increasing trend was also highlighted in the spring (March - April) and autumn and winter (September, November and December) as a result of precipitation, respective drainage and soils washing containing compounds with phosphorus.

3.3. Analysing the variation of chemical parameter concentrations with the average monthly flow rate for the years 2003 and 2006

Over time, the hydrological regime of the Danube River has evolved, influenced by several natural and anthropic factors, including anthropogenic activities and climate change. Lately, global climate disturbances have regional effects through exceptional processes and phenomena, sometimes catastrophic. The hydrological regime of the Danube River in the lower sector has been in recent years, under the influence of large scale disturbances of the precipitation regime, recording extreme variations of the water flow parameters.

This sub-chapter analyses the effect on the water quality of the variation in monthly average flows for 2 years very different from the hydrological point of view, particularly 2003 and 2006 in the Isaccea gauging station (km 100). The very large variation in annual and multiannual flow rates over the two years may be due to global climate change.

From a hydrological point of view, **in 2003**, the Danube River flows in the Isaccea station were above the normal monthly values in January and February and below these in the other months, the lowest values being registered in the period July - September when they were below 50% of the normal monthly values. In January 2003 the highest average monthly flow rate was recorded, respective 8280 m^3/s, the months of February - April being characterized by normal average values. Since April, average monthly flows are gradually decreasing until September, when it reached its lowest monthly average of 2500 m^3/s, then rising in October and November, and declining again in December. The year 2003 was characterized by an average annual flow of the Danube River at the Isaccea station of 5030 m^3/s, below the multiannual average of approx. 30% (Figure 11).

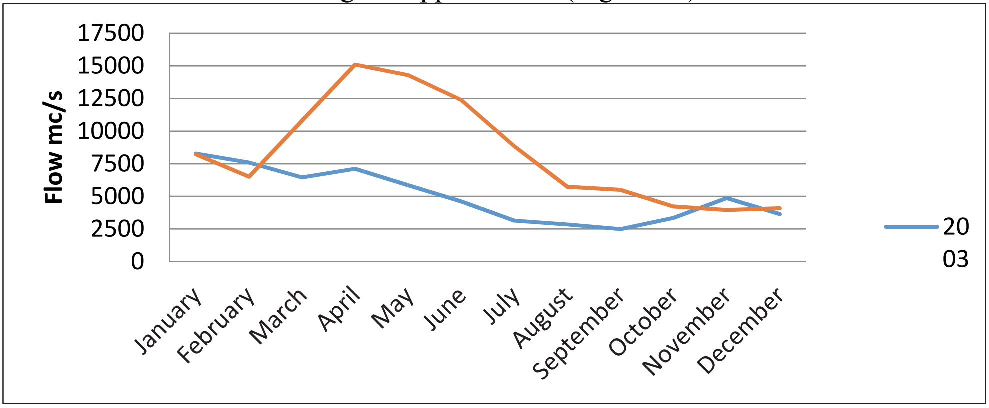

Figure 11. The variation of the average monthly flows for the years 2003 and 2006 in the Isaccea gauging station

From the point of view of the hydrological evolution of the Danube River in January-December **2006**, the exceptional floods recorded during the period April - May are highlighted, being the most important floods in the lower sector in the last 100 years, both in terms of maximum flows, but also from very long duration of floods levels point of view. Recorded historical flows have led to catastrophic floods, overflows and damages in several sectors of the Danube River, as well as important damages from socio-economic stand point.

The maximum flows recorded in April 2006 reached historical values higher than those recorded in 1970, 1981, values whose probability of exceedance was about 1% (the one hundred-year return period).

The year 2006 was characterized by an average annual flow of the Danube River lower sector at the Isaccea station of approx. 8310 m^3/s, over multiannual average of approx. 30%. In 2006, the Danube River flows in the Isaccea station were above the normal monthly values in the period January-September, particularly in the period March-July. Between March and June, average monthly flows varied in the range of 10,800-15,100 m^3/s, continuing in July with a high average flow rate but less than 10,000 m^3/s (Figure 11).

Considering the different characteristics of the *July - September 2003 period*, with average monthly flows (2500-3150 m^3/s) and the *March - June 2006* period, with extremely high average monthly flows (10,800-15,100 m^3/s), the average multiannual values (2001-2010) of the chemical indicators (oxygenation conditions: dissolved oxygen, BOD_5 and nutrient regime: N-NO3, N-NH4, N-NO2, P-PO4) were analysed and compared, respective the annual averages of the years

2003 and 2006, as well as of the decade (2001-2010) with the average values for the two extreme periods (Tables 2 and 3).

From the perspective of **2003** (Table 2), higher concentrations values for BOD_5 and P-PO4 are observed, as well as lower values of dissolved oxygen for the low-flow average period (July – September 2003) compared to the average of 2003 year or the decade average (2001-2010). Concerning dissolved oxygen, lower values are justified by decreasing the flow and the increase in water temperature and the biodegradable organic substances concentrations recorded between July and September 2003. Regarding the nitrogen parameters, their concentrations are lower during the low water period, being explained by increasing the rate of nitrification (ammonium transformation in nitrates) and algal growth with mineral nitrogen consumption.

Table 2. Comparison of chemical indicator values (decade average / average 2003 / July to September 2003 average) in the Reni monitoring *site*

Chemical indicator	Average 2001-2010 (mg/l)	Average 2003 (mg/l)	Average July-September 2003 (mg/l)
Dissolved oxygen	9.26	9.15	6.53
BOD_5	1.70	1.58	1.66
$N\text{-}NO_3$	1.65	1.91	1.02
$N\text{-}NH_4$	0.253	0.317	0.149
$N\text{-}NO_2$	0.041	0.057	0.040
$P\text{-}PO_4$	0.036	0.042	0.048

From **2006** year perspective (Table 3), higher values for $N\text{-}NO_3$ and $N\text{-}NO_2$ are observed for the average of the very high / extreme period, compared to the average of 2006 and the decade average (2001-2010). Regarding N-NH4 concentrations corresponding to the high water period, they record much higher values than the average decade value. With respect to dissolved oxygen, higher values are justified by increased flow and flow characteristics and decreased biodegradable organic substance concentrations recorded between March and June 2006.

Table 3. Comparison of chemical indicator values (decade average / average 2006/ March - June 2006 average) in the Reni monitoring site

Chemical indicator	Average 2001-2010 (mg/l)	Average 2006 (mg/l)	Average *March - June* 2006 (mg/l)
Dissolved oxygen	9.26	9.43	9.61
BOD5	1.70	2.04	1.78
$N\text{-}NO_3$	1.65	1.38	1.72
$N\text{-}NH_4$	0.253	0.335	0.336
$N\text{-}NO_2$	0.041	0.039	0.053
$P\text{-}PO_4$	0.036	0.041	0.029

With regard to nitrates, ammonium and nitrites, the higher average values for the high water period occur because of rainfall that drains, dissolves and entrains nitrogen-containing salts or suspended solids from the river basin. Decreases in P-PO4 concentrations during the high water period are registered having as main cause the dilution in the large volume of water.

Also, the variations in the dissolved oxygen concentrations values for the two years (2003 and 2006) were compared (Figure 12), observing, as noted above, that the reduced flow corresponding to the July-September 2003 period results in a decrease in the dissolved oxygen due to the increase of the water temperature and an increased impact of waste water discharges containing organic biodegradable substances.

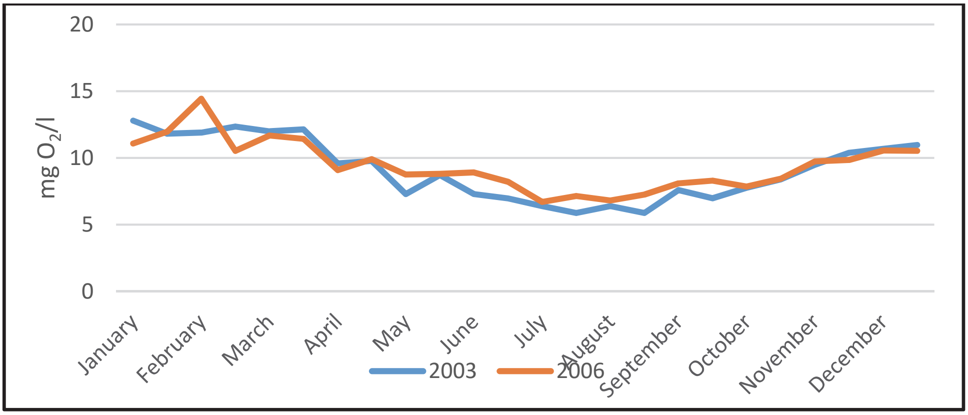

Figure 12. Variation of dissolved oxygen concentration for the years 2003 and 2006 in the Reni monitoring site

4.CONCLUSIONS

Assessing the effect of climate change on water quality in the lower Danube River sector have been studied, taking into consideration that both hydrological regime and water temperature, but especially seasonal variability, are influenced by global warming. The objective was to highlight the effects of changes in hydrological regime and water temperature on water quality in a representative monitoring site. From the chemical point of view, the studied parameters were dissolved oxygen, biochemical oxygen demand (BOD_5), nitrates, ammonium, nitrites and orthophosphates, analysing the multiannual variation of their concentrations, the monthly multiannual variation and the correlation with the variation of the water temperature of the studied period (1996-2014). From the point of view of the hydrological regime, the variation of the oxygen and nutrient parameters concentrations with the average monthly flow rate for the years 2003 and 2006 was evaluated in the Reni monitoring site. The limitations of this multiannual analysis on the Lower Danube River sector were: the relatively short period under review (19 years is a short period in terms of global change) and the impossibility of degrading only the effect of climate change on the rest of the factors, namely the variability of the anthropic pressures and the effect of the measures for improvement of water quality that have been implemented by the Danube countries.

In the context of the impact of climate change on water quality, the analysis of the multiannual variation in physical and chemical parameters (thermal regime, oxygen regime and nutrients conditions) for the period 1996-2014 shows an increasing temporal trend for dissolved oxygen and ortho-phosphates and a decreasing trend for biodegradable organic substances and inorganic nitrogen compounds, while water temperature has a quasi-stable trend.

The analysis of the monthly multiannual variations of the physico-chemical parameters with the water temperature was made in the context of the fact that the water temperature has a multiannual decrease trend for the months of January-July and an upward trend for the months of August-December, possible effect of global warming on water temperature. Based on the monthly multiannual trends highlighted for the water temperature, their effect on the parameters of the oxygenation and nutrients regime was studied considering the processes of the oxygen, carbon, nitrogen and phosphorus cycle, respectively the oxidation of organic substances, the nitrification-denitrification processes and development of phytoplankton.

The analysis of the variation of the chemical parameters concentrations with the average monthly flow rate for the years 2003 and 2006 revealed different results considering the different hydrological regimes. From the perspective of 2003, higher values for concentrations of BOD_5 and orthophosphates were observed, as well as lower values of dissolved oxygen, nitrates, nitrites and ammonium concentrations for the low-flow (July-September 2003) average compared to the average of 2003 or the decade average (2001-2010). In terms of 2006 year, higher average values for dissolved oxygen, nitrates, nitrites and ammonium concentrations were observed for the very high / extreme period (March – June 2006) compared to the 2006 average and the decade average (2001-2010).

REFERENCES

1. Gâştescu, P., Ţuchiu Elena, (2012), *Danube River in the lower sectşi catastrophe,or in two hidrologycal hypostases-high and low waters*, Riscuri şi catastrofe, An XI, vol. 10, nr. 1,Edit. Casa cărţii de ştiinţă, Cluj-Napoca,
2. Hosseini, N., Johnston, Jacinda, Lindenschmidt K-E, (2017), Impacts of climate change on the water quality of a regulated Prairie River, Water 2017, 9, 199;
3. Sorocovschi, V., (2017), *Fenomene şi procese hidrice de risc. Partea I, Domeniul continental*, Edit. Casa cărţii de ştiinţă, Cluj-Napoca;
4. Şerban, P. şi colab., (2006), *Analiza viiturii produse pe Dunăre în perioada aprilie-mai, 2006*, Hidrotehnica, vol. 51, București;
5. *** (2007), *Danube River Basin Monitoring Programs (Basin-wide Overview)/Raportul privind Programele de monitorizare în Districtul Hidrografic Internațional al Fluviului Dunărea*, International Commission for the Protection of the Danube River;
6. *** (2010), *Analiza regimului hidrologic al fluviului Dunării pe teritoriul României*, South East Europe, Danube Floodrisk;
7. *** (2012), *Danube River Basin Study on Climate Change Adaptation,* Ludwig-Maximilians University Munich, Germany;
8. *** (2014) Administraţia Naţională de Meteorologie, Proiect *ADER - Sistem de indicatori geo-referenţiali la diferite scări spaţiale şi temporale pentru evaluarea vulnerabilităţii şi măsurile de adaptare ale agro-ecosistemelor faţă de schimbările globale*, 2011-2014;
9. *** (2015), Ministerul Mediului și Schimbărilor Climatice și Banca Mondială, proiectul *Programul privind schimbările climatice și o creștere economică verde, cu emisii reduse de carbon*;
10. *** (2015), ICPDR – *Water Quality in the Danube Basin*, TNMN Yearbook 2015;
11. *** (2016), *Water Scenarios for the Danube River Basin – Elements for the assessment of the Danube agriculture-energy-water nexus*, European Commission, JRC Technical reports;
12. https://www.icpdr.org - Danube River Basin Water Quality Database (1996-2014).