Water Quality Analysis in Wetlands Freshwater: Common Floodplain of Jijia-Prut Rivers

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Water resources in the Jijia catchment basin are limited and often polluted. The catchment basin of Jijia is situated in northeastern Romania and it crosses the Moldavian Plain on the north-west-south-east direction. The purpose of the present study is to analyze 26 physico-chemical parameters providing the annual and multiannual water quality index. Two water-sampling points were selected: Jijia-Victoria [S.1] and Jijia-Opriseni [S.2]. The high values of nitrates are caused by the use of nitrogen-based chemical fertilizers and of manure. Contamination with nitrites (N-NO_2^-) and nitrates (N-NO_3^-) of wetlands and deepwater habitats in the floodplain of Jijia is still high because of agricultural and zootechnical activities. The phosphorus within freshwater habitats is a consequence of anthropogenic pressure: improper storage of animal waste and/or use of phosphates-based fertilizers. Global water quality index (WQ_i) shows that both monitoring stations are included in the Medium high class.

Keywords: Wetlands freshwater, floodplain, physico-chemical parameters, water quality index, anthropogenic activity

The analysis of water quality in wetlands freshwater and deepwater habitats exploited for fish farm, agro-zootechnical, and industrial purposes represents a major concern across the Globe. The contamination of these water reserves with pollutant substances can affect irreversibly the aquatic ecosystem and it can have major effects upon the health status of the population when this resource is also used for drinking water supply. From this perspective, the common floodplain of Jijia-Prut Rivers represents an important research area for northeastern Romania. The evaluation of water quality index (WQ_i) is a fundamental action in the management plan of aquatic resources. The ecological status of water bodies – irrespective of their natural or man-made origin – has changed continuously. The spatial dynamic of pollution sources and the water contamination risk is determined by a multitude of natural factors (geological substrate, land declivity, morphology of catchment basins, climatic changes, etc) and anthropogenic factors (wastewater discharge, industrial waters discharge, use of fertilizers, lack of septic tanks meant to prevent the infiltration of organic matter, etc).

The purpose of the present study consists in the descriptive and statistical analysis of 26 physico-chemical parameters providing the annual and multiannual water quality index in two monitoring stations within the common floodplain of Jijia-Prut Rivers: Jijia-Victoria [S.1] and Jijia-Opriseni [S.2]. The monitoring period was 4-12 count/year, between 2010 – 2016. The evaluation of waters quality was conducted in comparison with other catchment basins at national [1-19] or international level [20-26].

Experimental part

Study area

The common floodplain of Jijia-Prut Rivers is situated in the northeastern part of Romania and it overlaps an area with a central-southern position within the Moldavian Plain. Its limits are the following: northern limit – 47°25'01"N, southern limit – 46°54'50"N, western limit – 27°17'55"E, and eastern limit – 28°07'01"E. The western limit corresponds to a segment of natural frontier represented by the Prut River, between Romania and the Republic of Moldova [27]. The study area is situated on the territory of the Iasi County; it cumulates the territories of 20 communes and 50 localities. It covers 515.34 km^2, it is 89.45 km long; it has a maximum width of 19.41 km on the alignment of the localities of Iepureni–Popricani–Sculeni (the north of the area) and a minimum width of 3.26 km between the locality of Zberoaia and the Prut floodplain (the south of the area) (fig. 1).

A reduced density of the hydrographical network characterizes the catchment basin of the Jijia River, where speeds and flows are low. The riverbed is sculpted in clays and sandy clays that determine a natural increased turbidity of water. The lower sector of the basin belongs to a hydro-geomorphologic unit of floodplain common with the one of the Prut River. The main tributary of Jijia is the Bahlui River. The confluence occurs at the level of Tomesti, about 5 km downstream from the city of Iasi [27]. The floodplain is dominated by the interfluvial crests composing the right bank of Prut. Maximum altitudes are 280-300 m: they are known as the face of Prut. Minimum altitudes range between 10 and 20 m, and they characterize the Prut floodplain and the confluence area with the Jijia River at the level of the locality called Gura Bohotin. A longitudinal grind emerged between the two streams, and it is around 4–5 m higher than the runoff level, which included the creation of a common floodplain in the landscape on a relative distance of 50-60 km [28-30].

The common floodplain forms numerous zones with humidity excess known as wetlands. Most water bodies were turned into fish farms, drinking water supply basins,

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or polders for the mitigation of flood waves [31]. Most streams were regularized and transformed into irrigation channels. At the level of 2005, the aquatic surfaces in the Jijia-Prut common floodplain covered 25.35 km^2, which accounted for 4.91% within the total surface of the study area. At the level of 2012, the aquatic surface increased by +0.5 km^2 (25.85 km^2) and by 5.01% of the total surface, respectively [27]. The increase is a consequence of the active management exercised upon the lake units and upon the riverbeds in order to replace the fish farms, agricultural, and zootechnical activity. From the perspective of aquatic habitats, the common floodplain of Jijia-Prut has a special ecological value in the support for biodiversity. Environmental issues also concern the protection of archaeological sites of national importance [32-40].

Methodology

At the level of the common floodplain of Jijia-Prut Rivers, two water sampling sites were selected for the evaluation of chemism and of water quality: Jijia-Victoria [S.1] and Jijia-Opriseni [S.2] (fig. 2). They are an integrant part of the system of qualitative monitoring of strongly modified (artificial) water bodies within the lower basin of Jijia. The samples were collected in conformity with the manual of water quality monitoring system elaborated by the specialists of the Prut-Barlad Water Basin Administration. The monitoring period consisted of $2_{min.}$-$12_{max.}$ samplings/ year, between 2010-2016. Water samples were collected from two representative areas. Water quality was assessed pursuant to the quality standards issued by the Order of the Ministry of Environment and Water Management no. 161/ 2006. A second method was used for evaluating water quality index (WQI – statistical method) in order to determine the weighting of the 26 chemical and physico-chemical parameters.

The data collecting method led to the determination of the 26 chemical and physico-chemical parameters: Water transparency - Total suspended materials [mg/L] and Turbidity [NTU]; Thermal regime and acidifying - Air and water temperature [°C], *p*H [*p*H units] and Alkalinity [mmol/L]; Oxygen regime - Dissolved oxygen [mg O_2/L], Dissolved oxygen saturation [%], Biochemical oxygen demand [mg O_2/L] and Chemical oxygen demand (CCO-Mn and CCO-Br) [mg O_2/L]; Nutrients - Ammonium [mg N/L], Nitrites [mg N/L], Nitrates [mg N/L], Total nitrogen [mg N/L], Soluble orthophosphates [mg P/L] and Total phosphorus [mg P/L]; Salinity - Fixed residue [mg/L], Conductivity [μS/cm], Chlorides [mg/L], Sulfates [mg/L], Calcium [mg/L], Magnesium [mg/L], Bicarbonates [mg/ L], Total iron [mg/L] and Total manganese [mg/L]. In order to highlight the chemical characteristics and to evaluate water quality at the level of the common floodplain of Jijia-Prut Rivers at the end of an 1-year monitoring cycle in the 2010-2016 interval, a series of descriptive statistical parameters were determined: Average, Minimum, Maximum, Q1- Quartile 1 (25%), Q3 - Quartile 3 (75%) and Standard Deviation (tables 1, 2; figs. 3-8).

Results and discussions

Water transparency

Water transparency depends on the amount of total suspended materials comprising the suspended organic and inorganic matter, as well as on turbidity, temperature and/or water salinity. Within point S.1, the structure of banks comprises fine inorganic material; riverbed declivity is relatively high, while the sediments transported are made of fine inorganic material. Water speed is relatively constant (Q_{med} = 10.6 m^3/s; $Q_{max.}$ = 35.8 m^3/s - 08.07.2010), turbidity is high, while adjacent terrains lack vegetation. Within point S.2, the structure of banks and the composition of transported sediments are similar to the ones within S.1. Water speed in section S.2 - placed about 35 km downstream from S.1 - is higher ($Q_{med.}$ = 15.9 m^3/s; $Q_{max.}$ = 48.1 m^3/s - 09.07.2010).

On the date of sample collection, the average value of total suspended materials (TSM) was 194.2 mg/L in point S.1 and 137.4 mg/L in point S.2. The average value of water turbidity was 199.07 NTU in point S.1 and 119.58 NTU in point S.2. The maximum values of TSM and of turbidity correspond in both points to the periods of pluviometric peaks and / or spring thaw within the interval XI.2010 -

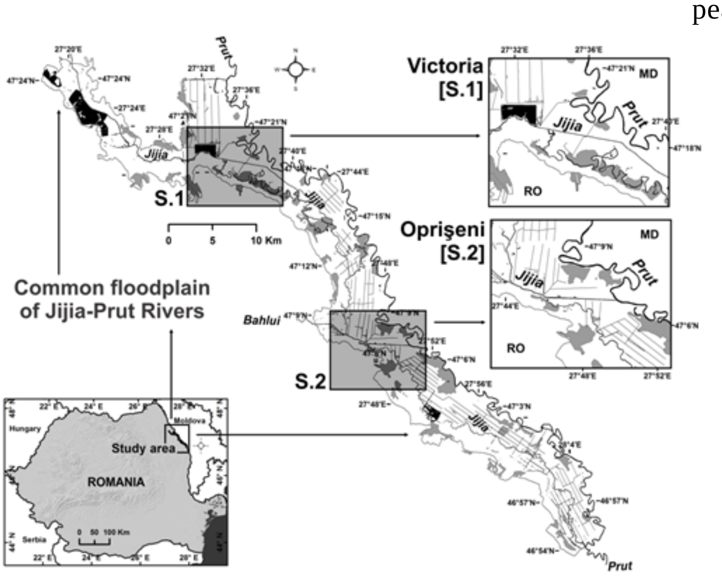

Fig. 1. Geographic position of the common floodplain of Jijia-Prut Rivers on the Romanian territory and the water samples sites: Victoria [S.1] and Opriseni [S.2]

Fig. 2. Water sampling sites Victoria [S.1] and Opriseni [S.2]

Table 1

DESCRIPTIVE STATISTICS FOR 26 CHEMICAL AND PHYSICO-CHEMICAL PARAMETERS ANALYZED IN VICTORIA [S.1] - UPPER AREA OF THE COMMON FLOODPLAIN OF JIJIA-PRUT RIVERS

Water sample – Victoria [S.1] – Common floodplain of Jijia-Prut Rivers									
Water quality indicators	Elements, chemical and physic-chemical indicators	Count \ year	Year (mean values)						
			2010	2011	2012	2013	2014	2015	2016
Transparency	Total suspended materials [mg/L]	4-12	362.2	455.4	101.0	180.9	104.5	66.0	89.4
	Turbidity [NTU]	4-12	407.8	531.4	98.5	110.7	97.1	55.4	92.7
Thermal regime and acidifying	Air temperature [°C]	4-12	14.1	14.2	12.0	6.2	14.0	13.9	12.1
	Water temperature [°C]	4-12	12.7	11.9	8.0	11.0	11.0	11.6	12.3
	pH [pH units]	4-12	8.1	8.2	8.2	8.2	8.3	8.2	8.0
	Alkalinity [mmol/L]	4-12	6.62	6.93	6.22	6.25	7.28	7.90	5.60
Oxygen regime	Dissolved oxygen [mg O_2/L]	8-12	7.92	9.58	10.38	8.74	8.41	8.71	8.61
	Dissolved oxygen saturation [%]	6-12	73.19	92.32	84.19	67.42	75.54	80.63	78.62
	Biochemical oxygen demand [mg O_2/L]	8-12	13.72	17.35	20.41	15.28	4.58	8.25	14.98
	Chemical oxygen demand (CCO-Mn) [mg O_2/L]	0-2	7.49	-	10.6	-	-	-	10.2
	Chemical oxygen demand (CCO-Cr) [mg O_2/L]	8-12	43.11	49.01	40.50	51.41	35.71	36.19	47.38
Nutrients	Ammonium (N-NH_4^+) [mg N/L]	8-12	0.72	0.56	1.40	0.56	0.26	0.25	0.32
	Nitrites (N-NO_2^-) [mg N/L]	8-12	0.040	0.039	0.039	0.033	0.031	0.023	0.031
	Nitrates (N-NO_3^-) [mg N/L]	8-12	2.19	1.11	1.68	0.93	0.78	0.55	0.60
	Total nitrogen (N) [mg N/L]	8-12	4.57	2.94	3.57	2.50	2.65	2.17	2.26
	Soluble orthophosphates (P-PO_4^{3-}) [mg P/L]	8-12	0.074	0.039	0.069	0.071	0.035	0.048	0.107
	Total phosphorus [mg P/L]	8-12	0.455	0.326	0.410	0.289	0.290	0.168	0.381
Salinity	Fixed residue [mg/L]	4-8	801.8	928.2	968.1	846.5	996	1069	-
	Conductivity [µS/cm]	4-8	1148	1298	1356	1202	1396	1422	1203
	Chlorides (Cl^-) [mg/L]	0-4	48.49	-	55.6	-	-	-	40.8
	Sulfates (SO_4^{2-}) [mg/L]	0-2	340	-	364	-	-	-	289
	Calcium (Ca^{2+}) [mg/L]	4-8	41.44	51.48	40.09	50.60	57.69	53.55	50.58
	Magnesium (Mg^{2+}) [mg/L]	4-8	47.30	50.96	56.37	63.38	66.63	67.96	47.10
	Bicarbonates [mg/L]	4-12	396.5	317.2	381.3	461.6	482.0	341.3	-
	Total iron (Fe^{2+} + Fe^{3+}) [mg/L]	0-2	3.46	-	4.10	-	-	-	1.98
	Total manganese (Mn^{2+} + Mn^{7+}) [mg/L]	0-2	0.31	-	0.56	-	-	-	0.12

Table 2

DESCRIPTIVE STATISTICS FOR 26 CHEMICAL AND PHYSICO-CHEMICAL PARAMETERS ANALYZED IN OPRISENI [S.2] - LOWER AREA OF THE COMMON FLOODPLAIN OF JIJIA-PRUT RIVERS

Water sample – Opriseni [S.2] – Common floodplain of Jijia-Prut Rivers									
Water quality indicators	Elements, chemical and physical-chemical indicators	Count \ year	Year (mean values)						
			2010	2011	2012	2013	2014	2015	2016
Transparency	Total suspended materials [mg/L]	4-12	249.6	221.6	53.5	234.8	40.0	54.4	108.0
	Turbidity [NTU]	4-12	282.4	220.9	52.0	130.0	31.1	47.2	73.4
Thermal regime and acidifying	Air temperature [°C]	4-12	13.6	13.7	14.5	11.3	13.6	14.5	14.6
	Water temperature [°C]	4-12	12.8	11.6	10.6	10.8	10.1	12.8	11.9
	pH [pH units]	4-12	7.9	8.1	8.2	8.2	8.3	8.3	8.0
	Alkalinity [mmol/L]	4-12	6.78	6.33	4.70	5.80	6.83	7.81	5.91
Oxygen regime	Dissolved oxygen [mg O_2/L]	8-12	6.51	10.42	9.00	8.02	9.47	9.82	8.49
	Dissolved oxygen saturation [%]	6-12	52.02	98.30	83.20	78.85	84.80	95.57	85.48
	Biochemical oxygen demand [mg O_2/L]	8-12	14.04	13.95	10.12	16.31	6.88	7.53	12.47
	Chemical oxygen demand (CCO-Mn) [mg O_2/L]	0-2	10.1	-	9.07	-	-	8.2	-
	Chemical oxygen demand (CCO-Cr) [mg O_2/L]	8-12	45.36	42.83	26.56	50.36	32.11	34.91	39.24
Nutrients	Ammonium (N-NH_4^+) [mg N/L]	8-12	1.53	0.34	0.65	0.61	0.43	0.20	1.56
	Nitrites (N-NO_2^-) [mg N/L]	8-12	0.206	0.076	0.119	0.211	0.084	0.073	0.158
	Nitrates (N-NO_3^-) [mg N/L]	8-12	2.82	3.87	5.57	4.94	4.95	2.79	2.06
	Total nitrogen (N) [mg N/L]	8-12	6.44	5.67	8.40	6.27	9.51	5.02	6.34
	Soluble orthophosphates (P-PO_4^{3-}) [mg P/L]	8-12	0.267	0.319	0.572	0.226	0.635	0.581	0.314
	Total phosphorus [mg P/L]	8-12	0.715	0.658	0.877	0.798	0.984	0.796	0.657

Salinity	Fixed residue [mg/L]	4-8	782.1	770.8	802.8	852.3	975.5	1049.4	-
	Conductivity [μS/cm]	4-8	1159	1168	1155	1198	1429	1440	1168
	Chlorides (Cl^-) [mg/L]	0-4	71.03	-	101.54	-	-	-	52.5
	Sulfates (SO_4^{2-}) [mg/L]	0-2	311	-	332	-	-	-	278
	Calcium (Ca^{2+}) [mg/L]	4-8	42.29	61.10	62.72	63.93	68.00	61.11	60.20
	Magnesium (Mg^{2+}) [mg/L]	4-8	49.05	47.17	35.73	49.10	52.87	59.79	51.51
	Bicarbonates [mg/L]	4-12	386.3	286.7	353.8	416.3	476.3	360.2	-
	Total iron (Fe^{2+} + Fe^{3+}) [mg/L]	0-2	8.95	-	10.2	-	-	-	4.02
	Total manganese (Mn^{2+} + Mn^{7+}) [mg/L]	0-2	0.40	-	0.54	-	-	-	0.21

IV.2011: S.1 – $TSM_{max.}$ = 3770 mg/L, $Turbidity_{max}$ = 3810 NTU; S.2 – $TSM_{max.}$ = 1567 mg/L, $Turbidity_{max.}$ = 1781 NTU (fig. 3). Water transparency increases by the degree of salinity and temperature. Water is colourless in the cold season, while in the transition seasons and during the summer, it varies from yellowish or brown-yellowish to brown, because of increased erosion and solid transportation.

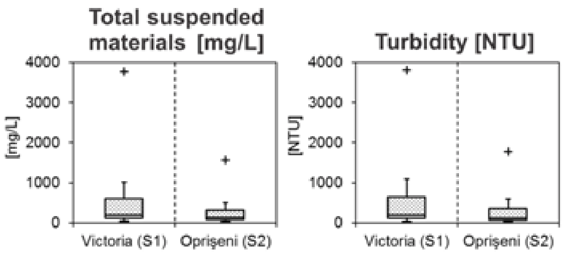

Fig. 3. Variation of water transparency between 2010 – 2016

Thermal regime and acidifying

The thermal regime of the areas is influenced directly by air temperature regime at the level of the aquatic surface. On the date of sample collection, the multiannual average air temperature varied between 12.35–13.68°C. Thermal amplitude is provided by the fact that water samples were collected in the two points in different days of the same month. For this reason, the difference between the thermal regime of air and water must be conducted separately. Within water sample S.1, multiannual average thermal amplitude between air and water – on the sample collection date - was 1.16°C and within the water sample S.2 it was 2.17°C. Hence, the difference in temperature increases from upstream downstream, with a constant of around 1°C between the two analyzed points. The difference is induced by the variation of water depth and aquatic surface, influenced directly by sun radiation. Air temperature on the date of sample collection has different values depending on season. Multiannual thermal amplitude is provided by the following intervals: S.1 0-28°C; S.2 0-27°C. Average water temperature in the hot season is 18-24°C, and in the winter, it varies between 1-7°C. In the transition seasons, temperature presents different value oscillations because of the thermal mixture with runoff waters from snow melting or precipitations, which reduces significantly the altitude influence of sun radiation (fig. 4).

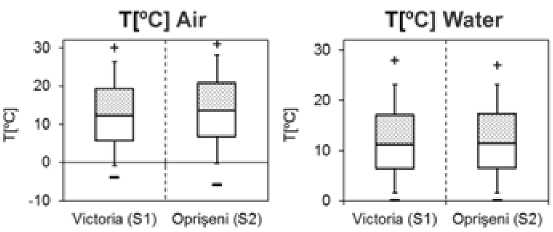

Fig. 4. Variation of thermal regime between 2010 – 2016

Air temperature regulates acidifying regime, through both the annual and seasonal distribution and through the night/day cycle. *p*H value has a significant variation gap, mostly during the day, because of photosynthesis, cenosis breathing, and aquatic fauna. *p*H has a relatively even distribution, with the following multiannual average value in the two points: S.1 - 815 pH units; S.2 - 8.14 *p*H units. The maximum value of pH was recorded for sample S.2 - 8.71 *p*H units due to the high temperatures in the month of August of the year 2015. The distribution of *p*H reflects the dominance of alkalinity. In point S.1, alkalinity value varies between 4.86-8.66 mmol/L and in point S.2 between 5.04-7.56 mmol/L. These values display a typical behaviour for rivers in hill areas, characterized by reduced flows, with stagnant and alkaline waters for most of the hot season, except for the spring shock, when acidity increases due to snow melting (fig. 5).

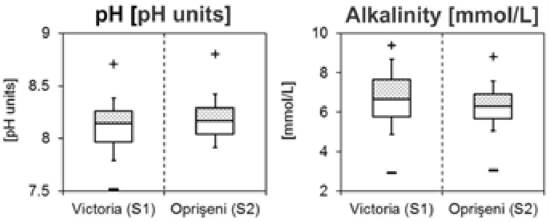

Fig. 5. Variation of acidifying conditions between 2010 - 2016

Oxygen regime

Water oxygenation degree is very important for the breathing of aquatic fauna and flora. The necessary amount of dissolved oxygen for the fish to survive must not drop below <5mg O_2/L. Oxygen decrease below this value indicates the need of a mechanism to replace oxygen. The multiannual average value of dissolved oxygen (DO_2) ranges between 8.81-8.91mg O_2/L. Between S.1 and S.2, the DO_2 amount decreases from upstream downstream because of water turbidity. As for samples S.1, the multiannual average value is >0.1mg O_2/L. The multiannual minimum value is only 2.15mg O_2/L in both stations. The phenomenon is closely connected to vegetation season and to oxygen demand by algae communities. The multiannual maximum values of DO_2 range between 12.2-12.8mg O_2/L. Saturation in DO_2 [%] shows multiannual average values increasing from upstream downstream because of water homogenization: S.1 - 78.84%, S.2 - 82.61%. The multiannual maximum values of saturation in DO_2 range between 131.4-152.2%, and multiannual minimum values identified in both points correspond to the interval 11.4-24.8%. Saturation in DO_2 increases significantly during the cold season and drops during the hot season, when minimum values are recorded. The correlation between DO_2 and air temperature is inversely proportional. The seasonal differences for this parameter can be explained by the oxidation occurring often in summertime (fig. 6).

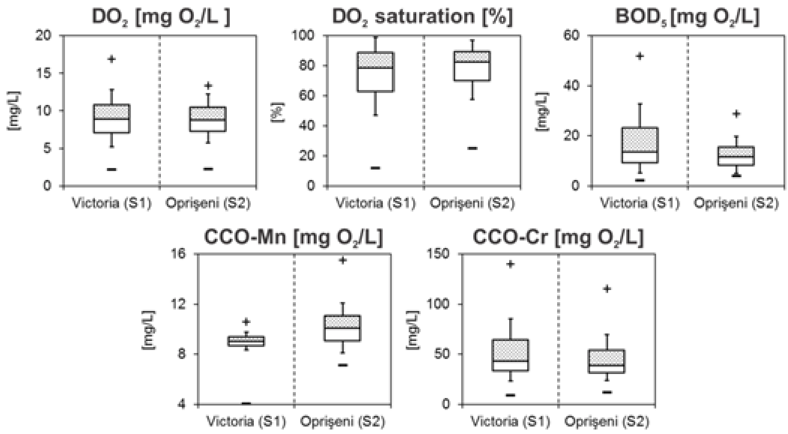

Fig. 6. Variation of oxygen regime between 2010 - 2016

Biochemical oxygen demand (BOD_5), specific to freshwater bodies, represents the amount of dissolved oxygen (DO_2) necessary for aerobic organisms to decompose organic matter in the water. A high level of BOD_5 indicates high contents in organic carbon from natural sources and a contamination from anthropogenic sources containing a significant amount of faeces. The multiannual value of BOD_5 varies as follows: S.1 -5.16-32.81 mg O_2/L; S.2 - 4.97-19.68 mg O_2/L. The very high amplitude of BOD_5 value is due to the accumulation of non-decomposed organic matter. The maximum value corresponds to a time interval where water was not evacuated and organic matter started decomposing. Minimum value corresponds to the periods with significant water circulation. The multiannual average value of BOD_5 is 13.51 mg O_2/L in the station of Victoria and 11.61 mg O_2/L in the one of Opriseni (fig. 6).

Chemical oxygen demand (CCO-Mn and CCO-Cr) is an indicator that determines the oxygen demand of bacteria in the water mass. This method is more rapid than the BOD_5 method, but it enables us to identify just 60-70% of the organisms in the water mass. The variation of the annual average of chemical demand using CCO-Mn is S.1 - 7.49-10.6 mg O_2/L and S.2 - 8.13-0.12 mg O_2/L. The variation of the annual average of chemical demand using CCO-Cr is S.1 35.71-51.41 mg O_2/L and S.2 32.11–-50.36 mg O_2/L. The multiannual average value at the level of the study area of CCO-Mn is 9.52 mg O_2/L and of CCO-Cr is 41.04 mg O_2/L (fig. 6). The agro-zootechnical and industrial infrastructure existing at the level of the common floodplain of Jijia-Prut Rivers reflects in the high values of BOD_5 and CCO-Cr indicators. The values of these indicators increase in summertime, when the amount of organic substances is high due to the vegetation season. The sudden increase in chemical and biochemical oxygen demand also occurs when there is a large amount of non-decomposed organic materials reaching the water mass after harvesting agricultural plants.

Nutrients

At the level of the two water quality monitoring sites in the wetlands area of the common floodplain of Jijia-Prut Rivers, nutrients were analyzed by identifying the concentration of ammonium ion (N-NH_4^+), of nitrites (N-NO_2^-), of nitrates (N-NO_3^-), and of soluble phosphorus (P-PO_4^{3-}). The presence of these toxic elements in the water mass is considered an indicator of pollution from anthropogenic sources. The multiannual average concentration of the ammonium ion (N-NH_4^+) varies in the two stations between 0.58–0.76 mg N/L. The maximum value for the sample of Victoria [S.1] is 6.35 mg N/L and for the sample of Opriseni [S.2] is 6.14 mg N/L. This concentration occurs in the spring and it is correlated with thaw and water runoff that dredges the agricultural land and transports ammonium in the hydrographical network. The lowest values are recorded in the hot season, but they do not drop below the level of 0.03 mg N/L in both points. In this case, the low values of ammonium ion concentrations are correlated with the temporary reduction of agro-zootechnical activities and they are the result of natural contaminations (fig. 7).

The amount of nitrites (N-NO_2^-) and nitrates (N-NO_3^-) within the analyzed water body indicates a relative contamination with these elements. At the level of S.1, the multiannual average concentration of nitrites ranges in the interval 0.023-0.040 mg N/L, and the multiannual average concentration of nitrates varies in the interval 0.54-2.18 mg N/L. At the level of S.2, the multiannual average concentration of nitrites ranges in the interval 0.07-0.20 mg N/L, and the multiannual average concentration of nitrates varies in the interval 2.06-5.56 mg N/L. The very high values of nitrates are caused by the use of nitrogen-

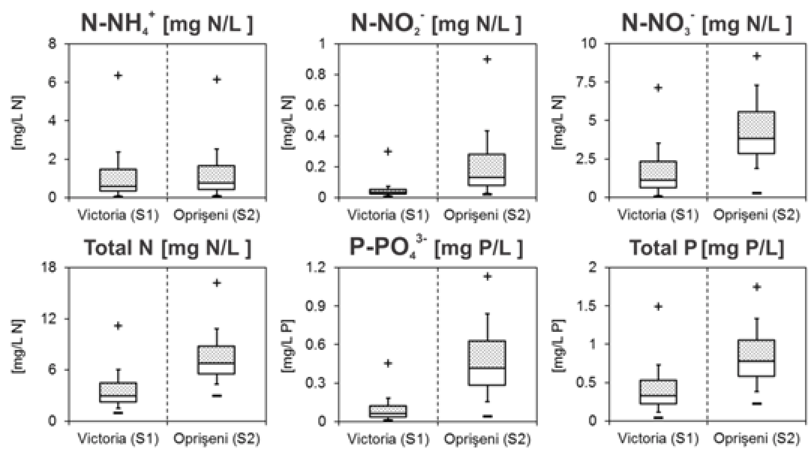

Fig. 7. Variation of nutrient concentrations between 2010 - 2016

based chemical fertilizers and of manure in the fertilization of agricultural fields along the rivers of Jijia and Prut. These streams collect nutrients through secondary irrigation channels or through the water table contaminated by water infiltration in the soil. For this reason, the highest value of nitrates concentrations corresponds to sample S.2 where, in the months of August-September of the year 2012, tests indicated a concentration of 9.03-9.20 mg N/L. The multiannual average value of total nitrogen indicates a quantitative increase from upstream downstream: S.1 – 2.95 mg N/L; S.2 - 6.81 mg N/L. The phenomenon is due to the elimination of nitrogen-fixing vegetation along the hydrographical network and to deeper riverbeds, which allow the transport of contaminated waters on great distances. The contamination of wetlands and deepwater habitats in the floodplain of Jijia with nitrites ($N\text{-}NO_2^-$) and nitrates ($N\text{-}NO_3^-$) is still high because of agricultural and zootechnical activities. At the same time, nitrogen contamination is also caused by natural sources, but to a lower degree (fig. 7).

Increased phosphorus content in freshwater aquatic habitats is usually a consequence of anthropogenic pressure, namely the improper storage of animal waste and/or the use of phosphates-based fertilizers. The multiannual average concentration of soluble phosphorus ($P\text{-}PO_4^{3-}$) varies between 0.063 mg P/L in the station of Victoria [S.1] and 0.41 mg P/L in the station of Opriseni [S.2]. Total phosphorus varies between 0.33 mg P/L in the station of Victoria [S.1] and 0.78 mg P/L in the station of Opriseni [S.2]. The most significant variation is recorded for sample S.2, where phosphorus has a maximum concentration range in the interval 0.22-1.75 mg N/L. As for sample S.1, the maximum value of soluble phosphorus concentration ($P\text{-}PO_4^{3-}$) does not exceed the level of 0.45 mg P/L. This distribution of phosphorus indicates a low contamination in the Jijia-Victoria area and a significant contamination in the Jijia-Opriseni area (fig. 7).

Salinity

The salinity of analyzed water samples is influenced directly by fluvial erosion and by the hydrogeological conditions in the common floodplain of Jijia-Prut Rivers. The presence of alluvial deposits specific to river floodplains determines the accumulation of high concentrations of mineral elements. The multiannual average value of fixed residue in the water mass indicates a very high erosion capacity in the surface (areolar) and at the level of riverbanks: S.1 – 934.9 mg/L and S.1 – 872.1 mg/L. The very high concentration of fixed residue also stands to show an accelerated erosion activity due to anthropogenic interventions at the level of the dredging network; by regulating the main stream of Jijia, these interventions led to higher water speed and capacity of transporting alluvia. The presence of a significant amount of salts is also due to the multiannual average value of water conductivity, which varies between S.1 - 1148-1422 μS/cm; S.2 - 1155-1440 μS/cm. The high value of conductivity is due to solid transport and to the accumulation of mineral substances in areas with stagnant water (fig. 8). In these conditions of salinity, the multiannual average concentration of chlorides (Cl^-) increases from upstream downstream, namely from S.1 - 48.49 mg/L to S.2 - 71.03 mg/L, and the multiannual average sulphate contents (SO_4^{2+}) decrease from upstream downstream, namely from S.1 -340 mg/L to S.2 -311 mg/L. The same spatial distribution trend characterizes the multiannual average value of calcium contents (Ca^{2+}) compared to magnesium contents (Mg^{2+}) in the water mass. Hence, the multiannual average calcium concentration (Ca^{2+}) increases from upstream downstream, namely from S.1 – 49.35 mg/L to S.2 – 59.9 mg/L, and the multiannual average magnesium contents (Mg^{2+}) decrease from upstream downstream, namely from S.1 – 57.1 mg/L to S.2 – 49.31 mg/L. Bicarbonates feature a spatial distribution identical to (SO_4^{2+}) and (Mg^{2+}), and the maximum concentration value lowers from upstream downstream, meaning from S.1 – 396.64 mg/L to S.2 – 379.93 mg/L. The presence of dissolved iron (Fe^{2+} + Fe^{3+}) and manganeses (Mn^{2+} + Mn^{7+}) is mostly due to the alluvial context within our study areas, but it may also be a consequence of pollution from anthropogenic sources. As for the station of Victoria [S.1], the multiannual average value of dissolved iron (Fe^{2+} + Fe^{3+}) is 3.46 mg/L and of total manganeses (Mn^{2+} + Mn^{7+}) is 0.31 mg/L. As for the station of Opriseni [S.2], the multiannual average value of dissolved iron (Fe^{2+} + Fe^{3+}) is 8.95 mg/L and the one of total manganeses (Mn^{2+} + Mn^{7+}) is 0.40 mg/L (fig. 8).

Water salinity is much higher during the cold season at both water quality monitoring stations. High values are usually correlated in the cold season, when low liquid runoff speeds and flows are recorded. The creation of ice bridges on the surface of aquatic surfaces or on surfaces with humidity excess represented a factor of control. In addition, salinity may also have a high value during the transition seasons. This type of salinity distribution is typical for wetlands and deepwater habitats within temperate zones (fig. 8).

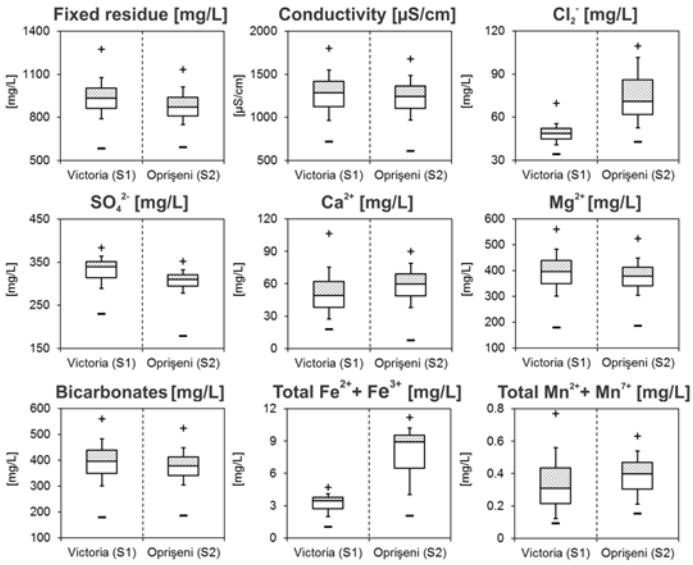

Fig. 8. Variation of fixed residue, conductivity and salinity concentrations between 2010 - 2016

Water quality index [WQI]

The global water quality index [WQI] was determined using two evaluation methods. The first method ascribes to the 26 physical-chemical parameters analyzed a class of water quality by the value of multiannual average concentrations. This method is in conformity with freshwater quality standards at the level of Prut-Barlad Hydrographical Space. In order to simplify the results, the evaluation was grouped into five categories, depending on the following: water transparency, thermal regime and acidifying, oxygen regime, nutrients, and salinity (table 3).

Water transparency -quantified in this study by the multiannual average value of total suspended materials (TSM) and of turbidity on the date of sample collection- indicates the third category of water quality in the two stations. However, the seasonal variation of these two parameters is very high and it stands to indicate the fact

Table 3

CHEMICAL AND PHYSICO-CHEMICAL STANDARDS OF QUALITY IN THE FRESHWATER WITHIN THE WATER QUALITY CLASSES OF THE COMMON FLOODPLAIN OF JIJIA-PRUT RIVERS

Water quality indicators	Elements, chemical and physical-chemical indicators	Standard classes of water quality					Common floodplain of Jijia-Prut Rivers	
		I	II	III	IV	V	Victoria S.1	Opriseni S.2
Transparency	Total suspended materials [mg/L]	No norms					III	III
	Turbidity [NTU]	No norms						
Thermal regime and acidifying	Air temperature [°C]	No norms					II	III
	Water temperature [°C]	No norms						
	pH [pH units]	6.5–8.5						
	Alkalinity [mmol/L]	-						
Oxygen regime	Dissolved oxygen [mg O_2/L]	9	7	5	4	<4	III	III
	Dissolved oxygen saturation [%]	90–70	70–50	50–30	30–10	<10		
	Biochemical oxygen demand [mg O_2/L]	3	5	7	20	>20		
	Chemical oxygen demand (CCO-Mn) [mg O_2/L]	10	25	50	125	>125		
	Chemical oxygen demand (CCO-Cr) [mg O_2/L]	10	25	50	125	>125		
Nutrients	Ammonium (N-NH_4^+) [mg N/L]	0.4	0.8	1.2	3.2	>3.2	III	III
	Nitrites (N-NO_2^-) [mg N/L]	0.01	0.03	0.06	0.3	>0.3		
	Nitrates (N-NO_3^-) [mg N/L]	1	3	5.6	11.2	>11.2		
	Total nitrogen (N) [mg N/L]	1.5	7	12	16	>16		
	Soluble orthophosphates (P-PO_4^{3-}) [mg P/L]	0.01	0.02	0.04	0.19	>0.19		
	Total phosphorus [mg P/L]	0.015	0.04	0.075	1.2	>1.2		
Salinity	Fixed residue [mg/L]	500	750	1000	1300	>1300	II	III
	Conductivity [µS/cm]	-	-	-	-	-		
	Chlorides (Cl^-) [mg/L]	25	50	250	300	>300		
	Sulfates (SO_4^{2-}) [mg/L]	60	120	250	300	>300		
	Calcium (Ca^{2+}) [mg/L]	50	100	200	300	>300		
	Magnesium (Mg^{2+}) [mg/L]	50	100	200	300	>300		
	Bicarbonates [mg/L]	-						
	Dissolved iron (Fe^{2+} + Fe^{3+}) [mg/L]	0.3	0.5	1	2	>2		
	Total manganese (Mn^{2+} + Mn^{7+}) [mg/L]	0.05	0.1	0.3	1	>1		
Total water quality							III	III

that in the period 2010-2016, water transparency depended largely on climatic conditions and on the management of water resources within the study area. This phenomenon is best observed for the station of Jijia-Victoria [S.1], where the influence of upstream lake reservoirs leads to increased TSM and water turbidity when controlled overflows occur. From the perspective of thermal regime and acidifying, station S.1 corresponds to the second quality class, while station S.2 to the third quality class. This distribution is provided by pH value, which increases from upstream downstream, directly proportionally with the multiannual average value of TSM.

Oxygen regime includes the samples of S.1 and S.2 in the third quality class, given the high values of BOD_5: S.1- 5.16-32.81 mg O_2/L; S.2 - 4.97-19.68 mg O_2/L and of CCO-Cr: S.1 - 35.71-51.41 mg O_2/L; S.2 - 32.11-50.36 mg O_2/L. According to the multiannual average concentration of the nutrients identified in the water mass, both stations are included in the third class of water quality. The only element included in the second class of water quality is the concentration of the ammonium ion: N-NH_4^+- 0.58-0.76 mg N/L, but the weighting of these values in the calculation of WQI based on nutrients is actually insignificant. According to the multiannual average distribution of water salinity, the sample of S.1 pertains to the second quality class, and the S.2 sample to the third quality class. As for the station of Jijia-Opriseni [S.2], the parameter that exceeds by far the water quality standards is the multiannual average concentration of dissolved iron (Fe^{2+} + Fe^{3+}) -8.95 mg/L, a value attesting a contamination from anthropogenic sources.

The second evaluation method for water quality was conducted using statistical methods consisting of calculating the weighting of the 26 chemical and physico-chemical parameters. The arithmetic value of water quality index (WQ_i) was obtained using the following formula (F.1), where Q_i is calculated for each parameter analyzed using the formula (F.2) and W_i is calculated for each parameter analyzed through the formula (F.3):

$$\text{(F.1)}\quad WQ_i = \Sigma WQ_i/\Sigma W_i$$

$$\text{(F.2)}\quad Q_i = 100[(V_i - V_o)/(S_i - V_o)]$$

$$\text{(F.3)}\quad W_i = K/S_i$$

where:

$K = 1/\Sigma(1/S_i)$; Q_i- quality rating scale; W_i - weight unit; V_i - the estimated concentration of the parameter in water; V_o - the ideal value of the parameter, $V_o = 0$ (except for *pH* = 7.0 and DO = 14.6 mg/L); S_i - the recommended

Table 4
WATER QUALITY SCORE IN THE COMMON FLOODPLAIN OF JIJIA-PRUT RIVERS BETWEEN 2010 – 2016

Common floodplain of Jijia-Prut Rivers		WQ_i Score / Year						
		2010	2011	2012	2013	2014	2015	2016
Water samples sites	Jijia-Victoria [S.1]	2.27	2.00	2.50	2.21	1.98	2.14	2.11
	Jijia-Opriseni [S.2]	3.16	2.94	3.11	3.16	3.11	3.00	3.16

WQ_i classes: 0–1 Excellent WQ_i; 1–2 Good WQ_i; 2–3 Medium high WQ_i;
3–4 Medium low WQ_i; 4–5 Poor WQ_i; >5 Very poor WQ_i

standard value of the parameter; K = the proportionality constant.

In the first phase of the statistical method, the variation of water quality index [WQ_i] was calculated based on annual average values for each of the 26 analyzed parameters. Hence, the result obtained enabled us to include water in a specific quality class (WQ_i classes: 0-1 Excellent WQ_i; 1-2 Good WQ_i; 2-3 Medium high WQ_i; 3-4 Medium low WQ_i; 4-5 Poor WQ_i; >5 Very poor WQ_i) depending on the section where sampling was conducted. In the period 2010-2016, in the water quality monitoring station of Jijia-Victoria [S.1], water quality varied between the *Good* and *Medium high* class. The year featuring the highest WQ_i was 2014, and the period with the lowest WQ_i was 2012. In the water quality monitoring station of Jijia-Opriseni [S.2], water quality varied between the *Medium high* and *Medium low* class. The year with the highest WQ_i was 2011, and the period with the lowest WQ_i comprised the years 2010, 2013, and 2016. According to these classifications during the analyzed interval, it is worth noting an important correlation between WQ_i in the two stations (table 4).

Based on calculating the weighting of physico-chemical parameters [W_i] used in the calculation formula for WQ_i, the dominant parameters for establishing the quality class were as follows: pH, oxygen regime (DO_2, BOD_5 and CCO-Cr), nutrients ($N\text{-}NH_4^+$, $N\text{-}NO_2^-$, $N\text{-}NO_3^-$ and $P\text{-}PO_4^{3-}$) and salinity (Cl^-, SO_4^{2+}, Ca^{2+}, Mg^{2+}, $Fe^{2+} + Fe^{3+}$ and $Mn^{2+} + Mn^{7+}$). From this perspective, oxygen regime within the S.1 and S.2 samples indicate a total WQ_i score corresponding to the *Medium high* class, accounting for the third quality class in conformity with freshwater quality standards at the level of Prut-Barlad hydrographical space. By nutrient regime, the total WQ_i score includes the samples of S.1 and S.2 in the same class of water quality as by oxygen regime. According to the score obtained for salinity concentration, sample S.1 indicates a total WQ_i score pertaining to the *Good* class, namely to the second quality class in conformity with freshwater quality standards at the level of Prut-Barlad hydrographical space. Sample S.2 indicates a total WQ_i score corresponding to the *Medium high* class (table 4).

The total WQ_i score includes both water quality monitoring stations- based on the analyses conducted in the period 2010-2016 - in the *Medium high* class. The main argument for the global WQ_i score obtained for wetlands and deepwater habitats in the study area is due to the contamination with certain chemical elements specific to the agro-zootechnical and industrial activities in the area (table 4).

Conclusions

Global water quality index [WQ_i] demonstrates the fact that the lower sector of the Jijia catchment basin is polluted; hence, it pertains to the *Medium high* class. The common floodplain of Jijia and Prut represents a very important agricultural unit; for this reason, it is mandatory to stop using chemical fertilizers. Such endeavour is stringent because the aridity of the area requires an intense exploitation of surface waters of groundwaters mainly for household use, including for drinking water supply.

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