ROMANIAN ACADEMY

INSTITUTE OF GEOGRAPHY

SUMMARY OF PhD THESIS

Study on the status of the water bodies from the lower sector of the Danube River between Baziaş and Isaccea

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CONTENT

INTRODUCTION

The PhD thesis is the follow-up of nearly 25 years of water management activity as a scientific researcher at the National Research and Development Institute for Environmental Protection, and then as a chemist, head of the Danube Management Plan office and since 2009 as Director of the Management Plan Department from the National Administration "Romanian Waters". The study also fructifies my experience as a member of working groups and expert groups at the level of the European Commission (Water Unit, Environment General Directorate) and of the International Commission for the Protection of the Danube River (ICPDR), as well as chair of the ICPDR's Pressure and Measures Expert Group (PM EG). At the same time, the doctoral school in the field of geography within the prestigious Institute of Geography has completed my knowledge in geography and hydrology and has significantly contributed to my multidisciplinary professional training so necessary to harmonise the quantitative and qualitative aspects into integrated water planning and management.

Study on the water bodies status on the lower sector of the Danube between Bazias and Isaccea is structured in 10 chapters which discuss the morphology, hydrography and management of water in the Danube River Basin. The hydrology and water quality are studied along the entire Danube course, along with the evaluation of its characteristic features from a hydrographical, hydrological, and qualitative perspective on the Danube lower sector and correlations between them, as well as the impact of climate change on water quality. Moreover, in the study new concepts and approaches in the water management at the European level are presented and analysed through implementation of the Water Framework Directive, as well as their implementation on the process of characterization and evaluation of the water status in water bodies on the Danube River, between Bazias and Isaccea.

After research history section, the chapter 1 presents *the morphological and hydrographical aspects of the Danube river basin*, as well as *the hydrology of the Danube River*. In the same chapter, it is analysed in detail the *water quality, with an emphasis on physico-chemical aspects of the entire Danube River course* through the interpretation of monitoring data obtained through the *Transnational Danube Monitoring Network* and the spatial-temporal evaluation of the physico-chemical quality of water for a period of 10 years (2006 - 2015) in 9 monitoring sites from Germany to Romania. In addition, on 12 monitoring sites of the entire Danube course, in the study is analysed, at a detailed scale, the spatial analysis of water quality from a physico-chemical and biological perspective afferent of the year 2015. The chapter 1 ends with aspects regarding *water management in the Danube River Basin* at the international level, through the cooperation of Danubian countries through the process of implementing the *Convention on cooperation for the protection and sustainable use of the Danube River* and in the context of the implementation of the Water Framework Directive.

In chapter 2, there are analysed the *hydrographical characteristics* of the lower sector of the Danube River, with details at the level of sub-sectors and the functions of the Danube floodplain and the morphological changes undergone during the last century. Following the *description of the monitoring system from a hydrological* point of view, the chapter 2 analyses the lower sector of the Danube through its two phases of high and low waters with the *analysis of multiannual minimum, average and maximal discharge* (1931-2016) and its respective tendencies, as well as *the influence of anthropogenic factors on the discharge regime.*

Chapter 3 analyses the *spatial and temporal variation of physico-chemical and biological quality indicators on the lower sector of the Danube,* chosen to reflect general characteristics, as well as the effect/impact of the main pressures identified on the basin for the period between 1996 and 2015, in representative monitoring sites. In addition, the *natural and anthropogenic factors which determine the variation of quality parameters* are identified and analysed along with their interdependence.

The analysis of the variation of physico-chemical parameters with the hydrological regime is presented in chapter 4 through the correlation of liquid flow with the loads of pollutants transported by the Danube, as well as with their respective concentrations based on the data from the qualitative load monitoring sites and the gauging stations for a period of 10 years.

The impact of climate change on the water quality of the lower Danube sector is assessed in chapter 5, studying *the multi-annual variation in oxygenation and nutrient regime parameters concentrations and correlation with water temperature* over two decades and *their monthly multiannual variation.* The variation of the *oxygenation and nutrient regime parameters concentrations with the extreme hydrological regime for the years 2003 and 2006* was also analysed.

In chapter 6, *the requirements of the European and national water legislation* are grounded in the context of the need to achieve and maintain good water status, as well as the stage *of implementation for the Water Framework Directive in Romania and results obtained at the national level in the process of elaborating and updating the National Management Plan.*

In Chapter 7 the *four water bodies located on the lower Danube sector were characterized in terms of their typology and delimitation, as well as from the point of view of anthropogenic pressures (point and diffuse pollution sources and hydromorphological alterations) their impact and the risk of failing to meet the environmental objectives*. In addition, the interdependence of the 4 bodies of surface water with groundwater bodies is studied and there were identified and mapped the protected zones that depend on the studied bodies of water.

The evaluation of ecological potential and chemical status of the water bodies between Bazias and Isaccea is the main objective in chapter 8. The results obtained (*the classification of water bodies in regards to their ecological potential and chemical status*) for the 4 bodies of water, as well as the evolution (comparative analysis) in regards to the two National Management Plans are presented in the same chapter. The chapter ends with a *proposal for the improvement of the manner in which water body evaluation methodology is applied from physico-chemical elements perspective* through the corroboration of all aspects analysed in this paper with the practical experience of developing and coordinating the two National Management Plans (2009 and 2015).

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On this occasion, I would like to thank my colleagues from the **Management Plans Department** for understanding, the human and professional quality and the appreciation I enjoy. I also thank other colleagues and former colleagues within the **Romanian Waters National Administration, the Ministry of Waters and Forests and the National Institute of Hydrology and Water Management**. I thank them for the guidance, appreciation and trust of my former directors (Corneliu A.L. Negulescu, Petru Şerban and Aurora Vasiu) who are now gone to eternity.

I have received a special support and scientific coordination from the **leadership of the Institute of Geography**, to whom I sincerely thank, but also for the honour of being part of the geographers family. Consideration, respect and gratitude for the members of the **Steering Committee** who coordinated me to complete this work.

I thank to ***Prof. Univ. Dr. Doc. Petre Gâștescu***, the scientific coordinator of the PhD thesis for the high level scientific guidance with which he honoured me, the professional and human support, the trust and the respect I enjoyed, the valuable time and the knowledge in the field of geography that he gave me.

Last but not least, I thank the family (the husband and children) for understanding, support, and love and I dedicate this PhD thesis to my parents for the education and love that surrounds me and my sister who protects me from the heaven.

KNOWLEDGE HISTORY OF THE DANUBE RIVER

A history on the knowledge of the Danube River, whether it is to be considered for its entire length (2860 km), from its sources (Brege and Brigach) in the Black Forest (Schwarzwald) in Germany, down to the Black Sea (Pontus Euxin), through its three branches of its delta (Chilia, Sulina and Sfantu Gheorghe) in Romania, or only for its lower sector (1075 km), it must be begun in antiquity. The Danube River, through its latitudinal placement on the European continent, has constituted an important waterway from ancient times, enabling exchanges – both at economic and cultural level, as well as military incursions.

The published papers on the lower sector of the Danube River can be grouped as follows: *Studies resulted from field research, topographical and geological maps, historical documents, statistical data on the geological, geomorphological, natural resources and population of the Danubian limes; hydrological researches realised through the processing and interpretation of data resulted from measurements made at gauging stations; complex monographic researches on geographical information, some made on the entire course of the Danube River; studies regarding management issues of the Danube River in the European context; studies regarding the Danube Strategy in the context of European legislation, especially the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC).*

The Bucharest Declaration constituted the base on which cooperation within the Danube River Basin has been developed, and in the present, it unfolds under the legal framework given by the *Convention regarding the cooperation for the protection and sustainable use of the Danube River (Sofia Convention, 1994)*, whose objectives refers to *the* *sustainable and equitable management of water, the improvement of water quality, the control of negative phenomena (accidental pollution, floods and ice hazard) and the reduction of pollutant loads.* In this respect, the International Commission for the Protection of the Danube River (ICPDR) was established, which ensures cooperation in the water management field. ICPDR also ensures coordination for the implementation of the *Water Framework Directive* through the development, update and implementation of the *Danube River Basin District Management Plan* and the *Danube River Basin District Flood Risk Management Plan*.

The *Danube Strategy* is implemented through the development and application of results from projects which are promoted within various programs financed by the European Union (ex. *Danube Flood Risk, Danube Water, Danube Sediment, Danube Floodplain*).

1. CHARACTERISATION OF THE DANUBE RIVER BASIN

1.1. Geographical considerations on the Danube River Basin - Morphological and hydrographical elements

The ***Danube,*** the second longest river in Europe (after Volga), springs from the Black Forest Mountains (Schwarzwald – Germany, Baden – Württemberg state) through tributaries Breg and Brigach under Kandel Peak (with an altitude of 1241 m) which join at Donaueschingen (678 m altitude). The Danube River is approx. 2860 km in length and has a river basin of approx. 817,000 km^2 that it is formed together with its 120 tributaries. Down to its flow into the Black Sea, the Danube drains (partially or even entirely) territories belonging to many European countries with various physical and geographic conditions. Its waterway runs through four capitals – Vienna, Bratislava, Budapest and Belgrade. Out of all Danube countries, Romania occupies 28.4% of its hydrographical basin, followed by Hungary (11.4%), Austria (10%), Germany (7%), etc. The sector of the Danube River that flows through Romania, inclusive its delta before its discharge into the Black Sea, is 1075 km long (38% of its total length) and partially constitutes the state border with Serbia, Bulgaria, Republic of Moldova, and Ukraine – figure 1.1 (Geografia României, vol. V,.2005).

The Danube River Basin is developed on varied relief units belonging or located nearby hercynian massifs on one side, and the mountain chains of the alpine-carpathian-dinaric-balkanic system on the other side. The characteristics of the river basin are strongly influenced by the major units of relief it passes through and the respective climate conditions.

Gates and gorges resulted out of breaking through by epigenesis or intake (Devin, Iron Gates), delineate the three sectors of the Danube: upper sector (alpine), middle sector (panonian), lower sector (pontic) (P. Gâştescu, 1998).

Figure 1.1. The Danube River from spring to the Black Sea

(https://commons.wikimedia.org/wiki/File:Danubemap.png#globalusage (Uses the map of Europe from the CIA World Factbook))

1.2. Hydrological considerations on the Danube River

The Danube hydric regime is characterized through large level and flow variations over the year and over time. In spring, following the melting of snows and the presence of heavy rains (nivo-pluvial feeding) the upper course experiences *spring high waters* during the interval May - June, and the middle and lower courses experience high waters during the period April - June. During autumn, *autumn low waters* occur, especially during September and October. During winter and summer, the discharge regime is characterized by moderate levels and flow.

Mean flow (1931-2016), as a consequence of tributary contributions, an increase in flow can be noticed from upstream to downstream. Thus, the upper sector has a flow of 1470 m^3/s in Passau and 1930 m^3/s in Vienna, as well as 2350 m^3/s in Budapest (figure 1.2). Upstream of Bazias, the Danube River receives three important tributaries (Drava, Tisa and Sava, with a total average flow of 2944 m^3/s) and enters the Iron Gates with an average flow of 5560 m^3/s. Along its lower course, through the contribution of tributaries on Romanian and Bulgarian territory, its average flow is of 6495 m^3/s in Ceatal Chilia.

Maximum flow is registered during spring high waters and, sometimes, may also occur during summer. As such, in April 2006, the maximum flow in the entire period of 1931 to 2016 was registered as 15,800 m^3/s at Bazias, 16,300 m^3/s at Giurgiu and 15,900 m^3/s at Ceatal Chilia.

Minimum flow occurs during autumn and sometimes during winter (1040 m^3/s at Bazias in 1949, 990 m^3/s at Gruia in 1985 and 1790 m^3/s at Ceatal Chilia in 1947) (P.Gâştescu, Elena Ţuchiu, 2012).

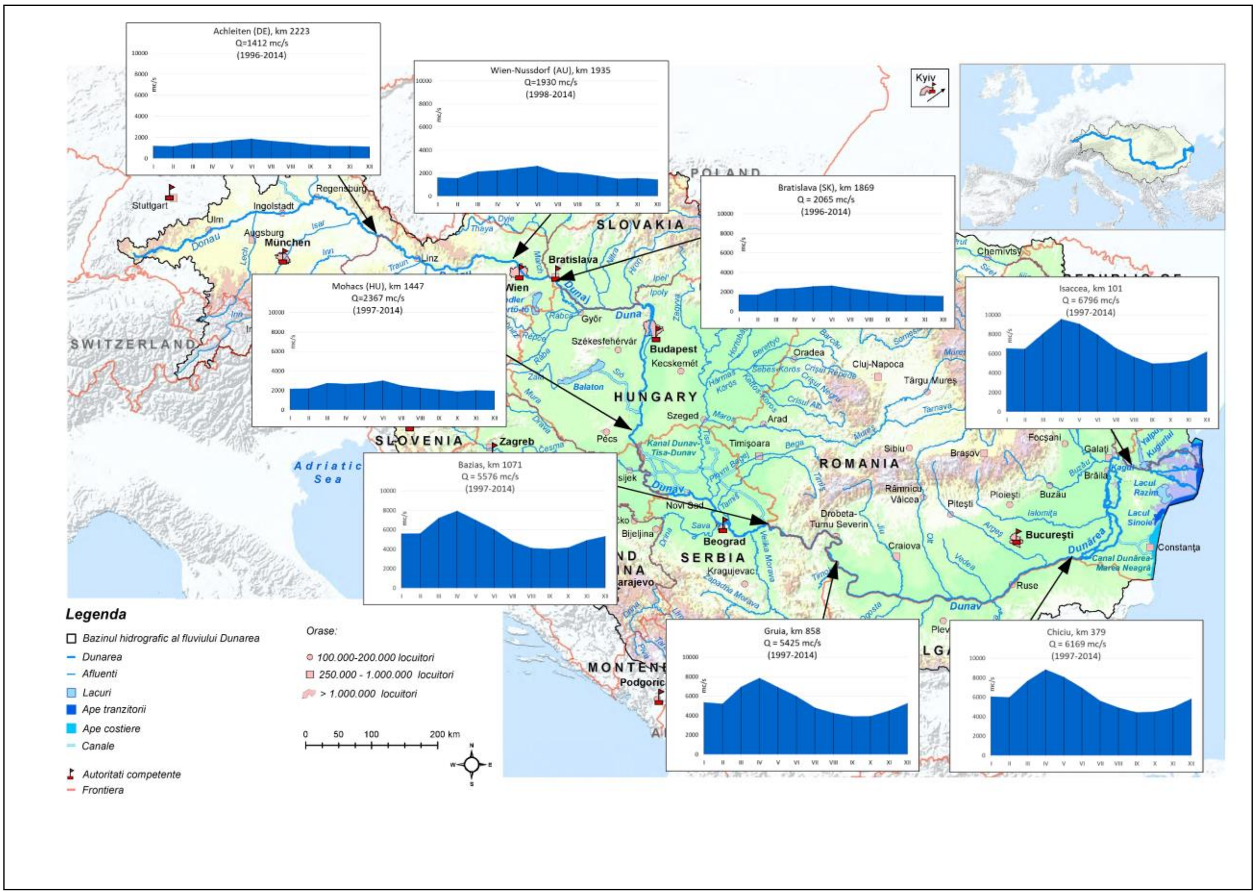

Figure 1.2. Variation of monthly multiannual average flows in the main gauging stations on the Danube River

The solid flow (1840-2000) consisted of 53 million tons per year, respectively 1681 kg/s. Extreme values registered during this interval were of 4470 kg/s (141 million per year) in 1871 and only 229 kg/s (7.2 million tons per year) in 1990. During the entire period, the tendency was towards a decrease with an annual rate of 8.3 kg/year, with variations which correspond to liquid flow (C. Bondar, 2000).

1.3. Water quality of the Danube River

The Danube TransNational Monitoring Network (TNMN) of the International Commission for the Protection of the Danube River (ICPDR) has been implemented in 1996. In 2000, the main objective of the TNMN has been developed in order to evaluate the water status (in accordance with the Water Framework Directive) and on long term the water quality and pollutant loads for the Danube River and its main tributaries. Since 2000, the implementation of the Water Framework Directive has required a review of the TNMN. This process was completed in 2007 through the Report regarding Monitoring Programs in the Danube River Basin District.

Water quality evaluation of the Danube River is analysed in this sub-chapter, taking both the spatial (from Germany to Romania) and temporal (the period between 2006 and 2015, focusing on 2015) variation of physico-chemical and biological indicators monitored in the main monitoring sites. For the spatial and temporal evaluation of the quality of the Danube River the following elements have been analysed: *physico-chemical indicators* structured in 6 categories: general indicators (water temperature, suspended solids, pH, alkalinity, conductivity, sodium, potassium, calcium, magnesium, chlorides, and sulphates), the oxygenation regime (dissolved oxygen, total organic carbon and the biochemical oxygen demand – BOD_5), nutrients (nitrates, ammonium, nitrites, inorganic nitrogen, total nitrogen, ortho-phosphates, and total phosphorus), heavy metals and metalloids (manganese, iron, zinc, copper, chromium, lead, cadmium, mercury, nickel, and arsenic), specific organic pollutants (phenolic index, anion-active detergents, adsorbable organic halides (AOX), and petroleum hydrocarbons) and organic micropollutants (pesticides: lindan, pp'-DDT, atrazine and volatile organic compounds: chloroform, carbon tetrachloride, trichloroethylene and tetrachloroethylene); *biological indicators* phytoplankton (chlorophyll a biomass) and benthic invertebrates (saprobic index).

The spatial evaluation of the Danube River water quality was conducted for the year 2015 across 12 monitoring sites (Dillingen, Jochenstein, Wien-Nussdorf, Bratislava, Szob, Hercegszántó, Novi Sad, Baziaș, Pristol, Oltenița, Chiciu and Reni) for the majority of physico-chemical indicators, taking minimum, average and maximal concentrations into consideration, as well as the 50% percentile (the median) and the 90% percentile (with the sole exception of dissolved oxygen, where the 10% percentile was considered). From the chemical point of view, *the upstream downstream spatial variation* of average annual concentrations (2015) is increasing for most parameters, showing the transport and accumulation of polluting substances. Some indicators/parameters (alkalinity, calcium, potassium, iron, nitrates, inorganic nitrogen and total nitrogen) have been observed to have a decreasing spatial tendency.

The evaluation of spatial and temporal tendencies during a period of 10 years (2006-2015) was conducted across 9 monitoring sites (Jochenstein, Hainburg, Bratislava, Szob, Hercegszántó, Borovo, Pristol, Chiciu și Reni), using annual mean values for 6 physico-chemical parameters (suspended solids, chlorides, BOD_5, inorganic nitrogen, ortho-phosphates, and total phosphorus), which were selected for their relevance. *From spatial perspective*, with the exception of inorganic nitrogen which has a tendency to decrease in its mean multiannual concentration (2006-2015) from upstream to downstream, all other parameter concentrations have increased from Jochenstein to Reni (figures 1.3 to 1.6).

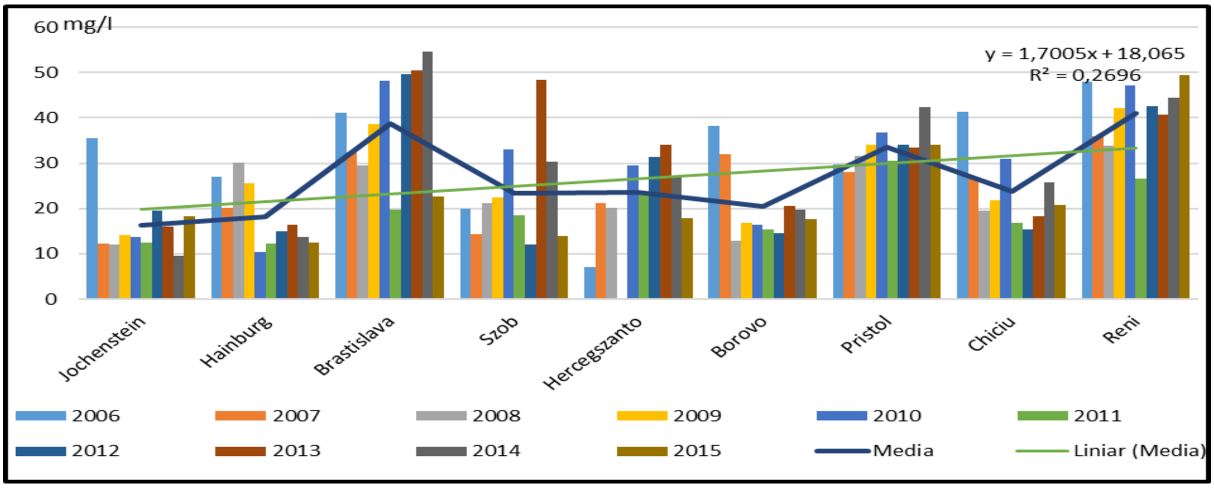

Figure 1.3. Variation of the annual and multiannual average values (2006-2015) of suspended solids concentrations on the Danube River

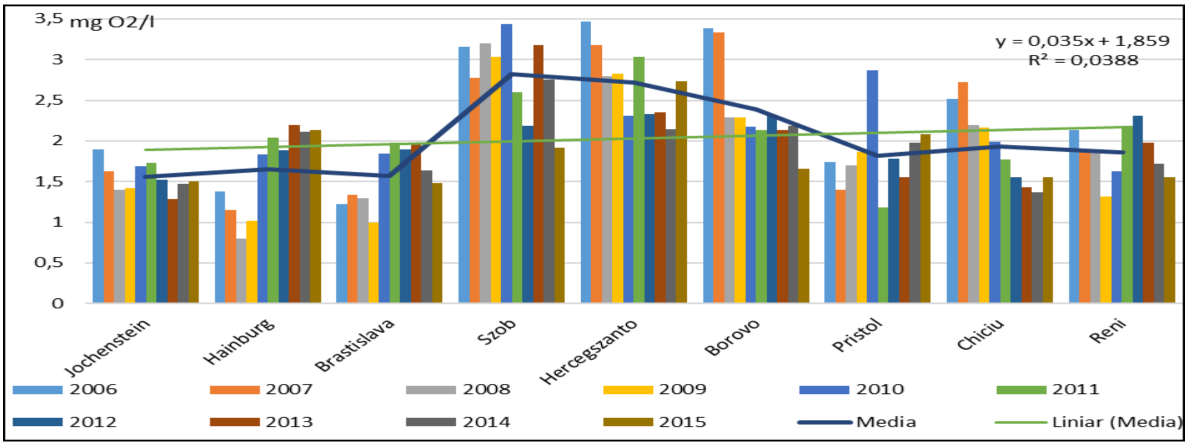

Figure 1.4. Variation of the annual and multiannual average values (2006-2015) of BOD_5 concentrations on the Danube River

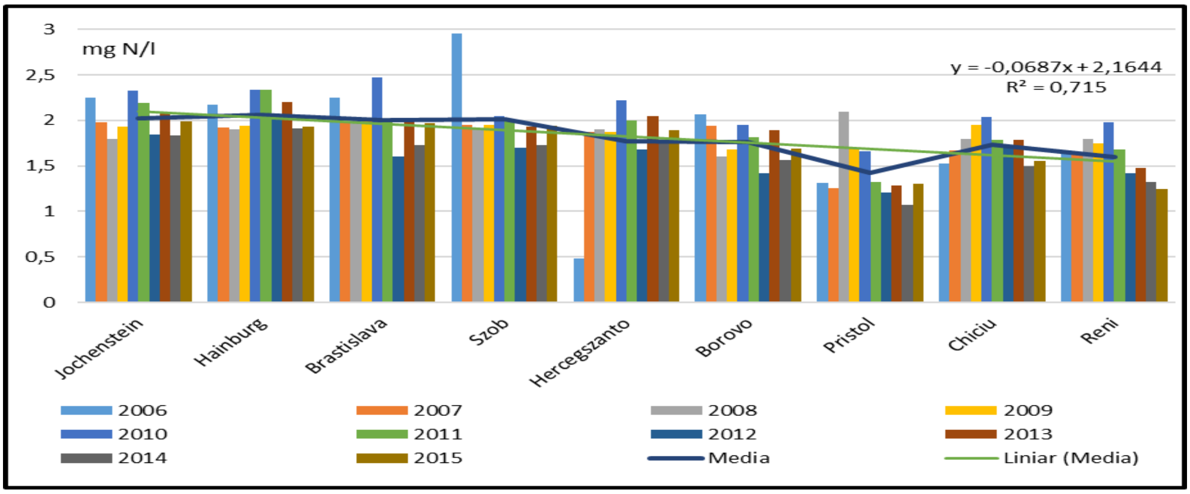

Figure 1.5. Variation of the annual and multiannual average values (2006-2015) of total nitrogen concentrations on the Danube River

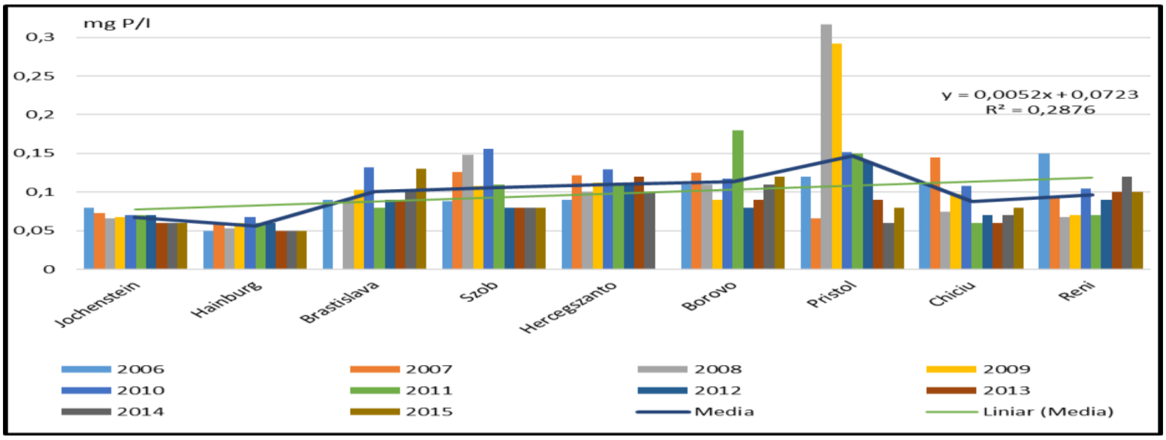

Figure 1.6. Variation of the annual and multiannual average values (2006-2015) of total phosphorous concentrations on the Danube River

From temporal point of view, it should be noted that the mean annual concentrations are decreasing for the 2006-2015 period, especially for organic substances and nutrients (BOD_5, inorganic nitrogen, ortho-phosphates and total phosphorus), thus showing an improvement in Danube water quality, mainly as an effect of measures taken to reduce pollution.

1.4. Water management in the Danube River Basin

Cooperation in the water field in the Danube River Basin is done in conformity with the *Convention regarding the cooperation for the protection and sustainable use of the Danube River (Sofia Convention, 1994).* On the basis of the Danube Convention, the *International Commission for the Protection of the Danube River (ICPDR)* was established to ensure cooperation on important and transnational water management issues. In addition, ICPDR creates the institutional and technical coordination framework, in an international context, for the implementation of the Water Framework Directive. *The first Danube River Basin River District Management Plan* (part A) was finalized in 2009 and treated important issues on water management. It has been updated in 2014-2015, following the same approach. In conformity with the *Danube River Basin District Management Plan (2015),* for *surface water*, long term visions have been established, along with management objectives for the reduction/attenuation of effects caused by anthropomorphic pressures, such as *pollution with organic substances, nutrient pollution, pollution with hazardous substances and hydromorphological alterations.*

2. HYDROGRAPHICAL AND HYDROLOGICAL CHARACTERISTICS OF THE LOWER SECTOR OF THE DANURE RIVER

2.1. Hydrographical characteristics

The lower course (pontic), according to its morphohydrographic configuration, riverbed and floodplain, subdivides in sectors: *Baziaş-Gura Văii, Gura Văii-Călăraşi, Călăraşi-Ceatal Chilia (Pătlăgeanca)* to which the *Danube Delta* can be added, with its own particularities (Geografia României, vol. 5).

The Baziaş-Gura Văii sector has a length of 132 km. It is known by its toponym *The Iron Gates Gorge,* one of the best-known gorges in Europe. The Danube cut through the Carpathians through Cazanele Mari (3.5 km) and Cazanele Mici (5.5 km) depressions. Through the building of the reservoir, the morphohydrological configuration was altered, as well as the hydrological regime of the Danube into a semi-lacustrine (poly dynamic) regime. The Iron Gates hydropower and navigation system was inaugurated in 1971. Gura Vaii dam has a length of 1278 m and a hydropower plant with a total power of 2100 MW.

The Gura Văii-Călăraşi sector has a length of 566 km, with a riverbed ranging between 500 and 1500 m and is characterized by a high degree of meandering, with multiple river islands. The floodplain is fragmented until Basarabi-Calafat, from which it continues in varying lengths ranging from hundreds of meters to several kilometres. The Danube, in this sector, receives numerous tributaries, both from Bulgaria - Timok, Ogosta, Iskar, Vit, Iantra, and Romania – Drincea, Jiu, Olt, Vedea, and Argeș. A second reservoir was built in this sector, Ostrovul Mare, inaugurated in 1986, with a hydropower plant of 410 MW (Geografia României, vol.V, 2005).

The Călăraşi –Ceatal Chilia (Pătlăgeanca) sector has 300 km and is divided in two subsectors: Balta Ialomiței – Brăilei and the Danube's maritime sector Brăila – Ceatal Chilia. Balta Brăilei and Balta Ialomiței/Borcei have a length of 195 km and are delineated by two main branches of the Danube River. Both, Balta Ialomiței and Balta Brăilei had an important significance as wetlands before the construction of dykes and their subsequent draining. In the maritime subsector Brăila – Ceatal Chilia (Pătlăgeanca), the Danube's average flow, due to tributaries such as Siret and Prut, is of approx. 6500 m^3/s at Ceatal Chilia. Upstream Pătlăgeanca, the Danube River flows in a single riverbed and creates floodplains on its right bank where lacustrine complexes have developed, alternating with calcareous promontories that reach out to the riverbed (Isaccea).

By size and complexity, ***the Danube floodplain*** is the most important morphohydrographical formation unfolding mainly on the left bank, downstream from the Iron Gates Gorge, on the territory of Romania. On the territory of Romania, the Danube floodplain with a surface of ***5500 km²*** (without delta), through the dykes construction action, which was modestly begun in 1904-1916 with Chirnogi, continued with Mănăstirea, Luciu, Giurgeni and generalised during 1960-1990, was dammed between Gruia and Isaccea on a surface of **4380 km² (79.6%)** and was divided in 53 modules (Ioaniţoaia şi colab.2007, Mihailovici şi colab. 2006). If until the beginning of the 1950's the Danube floodplain was one of the most important wetlands in Europe, with natural and semi-natural ecosystems of which approx. 45% were *permanent aquatic ecosystems* flooded for 3 to 4 months per year during high water periods, today the majority of them have been reduced/modified. Thus, in its natural condition, the floodplain fulfil important functions such as: *the hydrological function, the biochemical (ecotonal) function, the climatic function, the socio-economic function*, functions which have been largely lost through floodplain damming.

2.2. Hydrological regime characteristics

The Danube River hydrological regime is relatively uniform; the ratio between its maximum and minimum flow is 1/10. In the analysis of the hydrological regime of the Danube River in its lower course, the conditions of forming/determination of discharge on the upper and middle sectors must be taken into consideration.

Data from the period between 1931 and 2016 is used in the analysis for the entire hydrological spectrum, average, maximum and minimum flow. Through the analysis of ***flow***, along the 1075 km of the Danube's lower sector, an increase in ***multiannual average flow*** can be observed from upstream – Baziaș (5561 mc/s) towards downstream – Ceatal Chilia (6495 mc/s), as well as ***minimum flow*** (1040 mc/s at Baziaș and 1790 at Ceatal Chilia) and ***maximum flow*** (15800 mc/s at Baziaş and 15900 at Ceatal Chilia), as a result of the contribution of tributaries (figure 2.1).

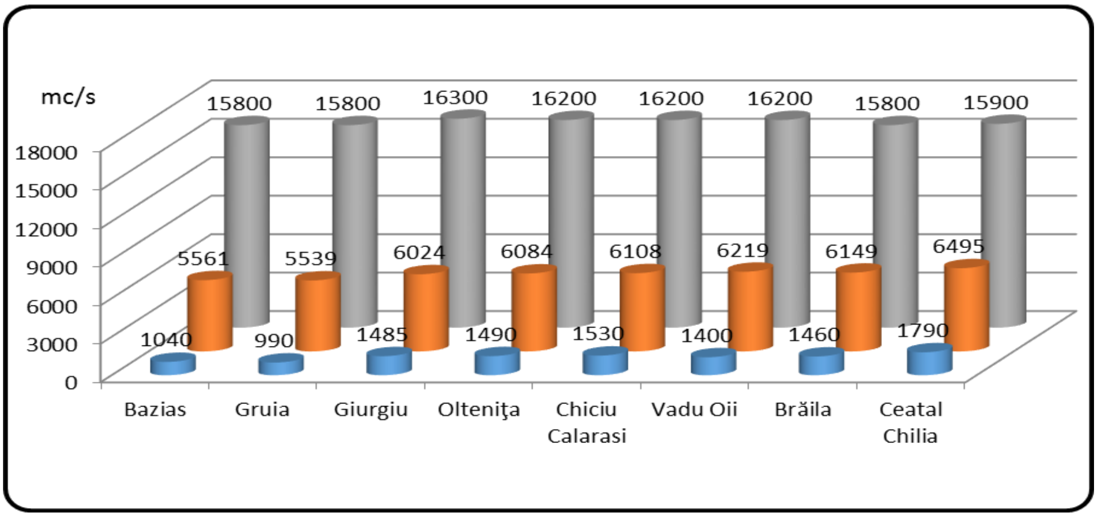

Figure 2.1. Multiannual, maximum and minimum annual average flows in the main gauging stations (1931 – 2016)

Analysing the variation of average, maximum and minimum annual flows at the two extreme gauging stations, Baziaș – at the entrance in the Iron Gates Gorge and Ceatal Chilia – upstream the Danube Delta, the tendencies of these hydrological parameters can be observed, for the period 1931-2016. Thus, ***the average annual flows*** at the Baziaș gauging station register a slow tendency of decreasing, as is resulted from the polynomial analysis, in opposition to those from the Ceatal Chilia gauging station, where the tendency is towards a slight increase (figures 2.2 and 2.3)

The minimum annual flows at both stations (at the entrance in the gorge and delta), has a tendency of increasing. The **m*aximum annual flows*** in the period between 1931 and 2016, as resulted from the polynomial analysis have a slight increasing tendency at the Baziaș gauging station and a sensible increasing tendency at the Ceatal Chilia gauging station.

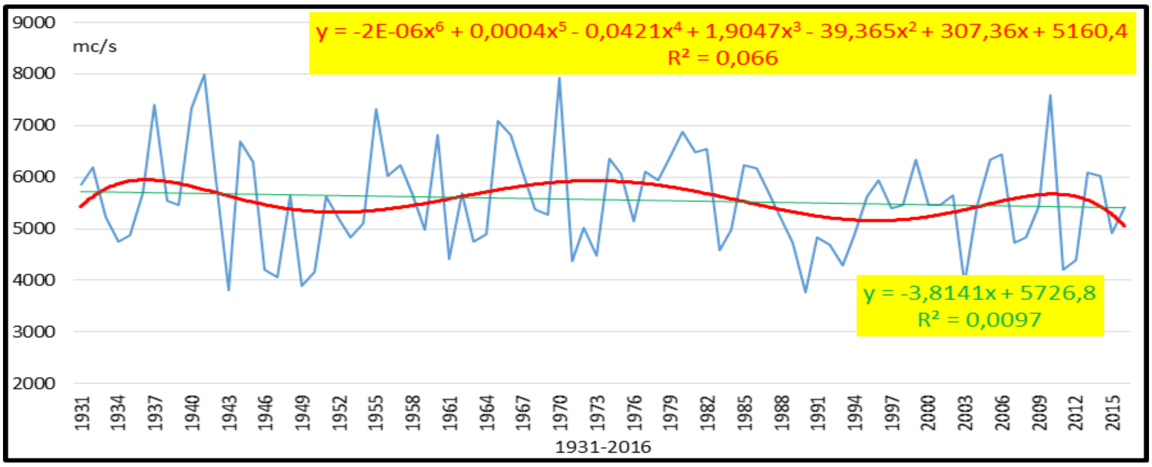

Figure 2.2.Variation of annual average flow at Baziaş (1931-2016)

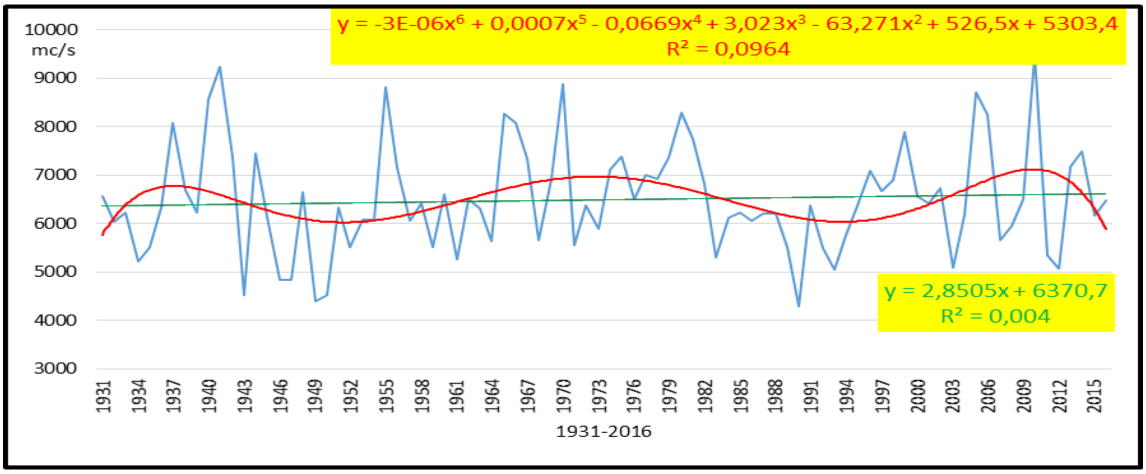

Figure 2.3. Variation of annual average flow at Ceatal Chilia (1931-2016)

Regarding **the flow of suspended solids** transported by the Danube in the last century in Isaccea site, these have dramatically decreased (figure 2.4).

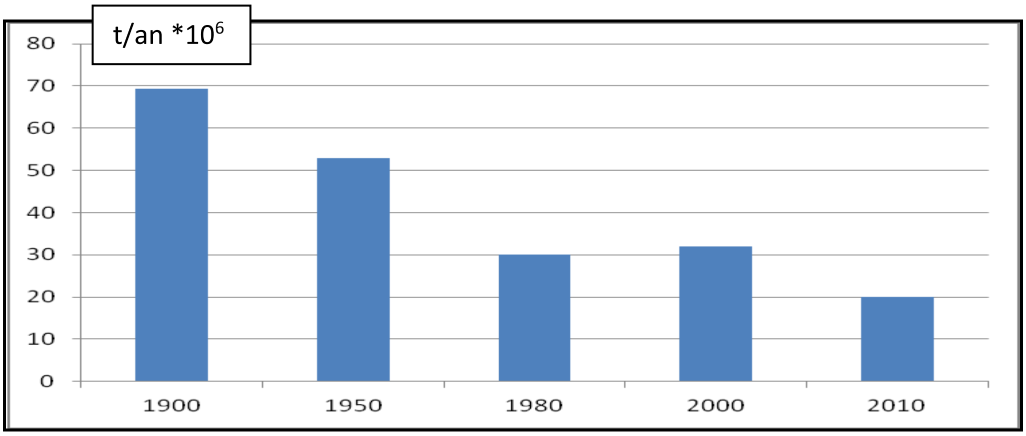

Figure 2.4. Decreasing the annual flow of suspended solids carried by the Danube River at Isaccea gauging station *(processed from INHGA study)*

2.3. Influence of the anthropogenic factors on discharge regime

The anthropogenic factors represent human activities that use the socio-economic potential of the river, having a direct influence on the river's natural hydrological regime. Thus, in time, the Danube's hydrological regime gradually suffered important changes, directly linked to: the building of big hydropower projects along the Danube River (the Iron Gates and Ostrovul Mare hydropower and navigational systems), works on the river for improving the navigation conditions (Iron Gates Gorge, the Borcea branch of the Danube, the maritime sector of the Danube) and ports and shipyards built along the river, the protection of vast areas against flooding and their reallocation towards urban development and agriculture (floodplain damming projects downstream from Drobeta Turnu Severin), the use of water for irrigation (hydrotechnical constructions, water intakes for irrigation), the development and exploitation of complex waterworks on the Danube's main tributaries (reservoirs for complex use, especially on rivers Cerna, Jiu, Olt, Argeş, Dâmboviţa, Ialomiţa, Siret, and Prut); river bed dredging, as well as the improvement of navigation conditions through the enlargement of transportation possibilities (dredging projects with quantities of approx. 2.08 mil. m^3/year until 1990).

3. WATER QUALITATIVE CHARACTERISTICS OF THE LOWER SECTOR OF THE DANURE RIVER

3.1. Introductory aspects

The water quality analysis in the lower sector of the Danube River (sector Baziaș – Isaccea) was done using the data from 6 monitoring sites that are part of the Danube TransNational Monitoring Network (TNMN) of the International Commission for the Protection of the Danube River (ICPDR), respective: Baziaș, Gruia, Pristol, Oltenița, Chiciu and Reni.

This chapter analyses the spatial and temporal variation of physico-chemical and biological qualitative indicators, selected in order to illustrate the general characteristics (general indicators), as well as the effect/impact of the main pressures identified on the Danube River Basin level: organic pollution, nutrient pollution and hazardous substances pollution. The set of indicators selected for the evaluation of water quality from a ***physico-chemical*** point of view contained **general indicators** *(thermal conditions – water temperature; suspended solids; acidification status – pH and alkalinity; salinity – conductivity, cations – sodium, potassium, calcium, and magnesium, anions – chlorides and sulphates),* **oxygenation conditions** (*dissolved oxygen,* organic substances measured through *BOD_5, CCO-Mn, CCO-Cr* and *total organic carbon - TOC*), **nutrient conditions** (*ammonium, nitrates, nitrites, total nitrogen, ortho-phosphates, total dissolved phosphorus* and *total phosphorus*), **heavy metals and metalloids** (Iron, Manganese, dissolved Zinc, dissolved Copper, dissolved Chromium (Cr^{III} and Cr^{VI}), dissolved Lead, dissolved Cadmium, dissolved Mercury, dissolved Nickel, dissolved Arsenic), **specific organic pollutants** (*phenolic index – phenols, anion-active detergents and petroleum hydrocarbons*) and **organic micropollutants** (*pesticides – pp'DDT, Lindan and Antrazin*). In regards to ***biological*** elements/parameters, the water quality analysis took *benthic macroinvertebrates (saprobic index)* and *phytoplankton (chlorophyll a biomass)* into consideration.

The period analysed is between 1996 and 2015 (20 years) for all monitoring sites, except Gruia site, which has been monitored since 2007.

3.2. Water quality analysis of the lower sector of the Danube River

The water quality analysis of the lower sector of the Danube River in 6 monitoring sites highlights the following:

- Minimum, average and maximum multiannual values have been calculated for all determinants, which have described the variability scale of concentrations values for the analyzed periods. In addition, the values obtained have been interpreted and justified, especially from the perspective of interdependence between the parameters, their behaviour, aquatic transformations/reactions, respective sedimentation phenomena as well as their correlation with the contribution of tributaries and pollution sources;
- Upstream – downstream variations have been established. Thus, some determinants have a spatial decreasing trend (water temperature, conductivity, sodium, potassium, calcium, magnesium, chlorides, dissolved oxygen, BOD_5, CCO-Cr, CCO-Mn, TOC, nitrates, nitrites, ammonium, nitrogen, iron, copper, arsenic, petroleum hydrocarbons, DDT, lindan, atrazine, chlorophyll) and some have an increasing trend (sulphates, ortho-phosphates, total phosphorus, manganese, zinc, lead, cadmium, mercury, nickel, macrozoobentos); some have remained approximately constant (alkalinity, phenols, detergents) – figures 3.1 – 3.15;
- All analysed determinants have been evaluated from temporal point of view, with observations of the improvement of water quality (for conductivity, sodium, potassium, calcium, magnesium, chlorides, phosphates, dissolved oxygen, BOD_5, CCO-Cr, CCO-Mn, nitrates, nitrites, ammonium, total nitrogen, ortho-phosphates, iron, manganese, zinc, copper, chromium, lead, cadmium, mercury, petroleum hydrocarbons, chlorophyll a biomass) or a slight decrease of water quality (nickel, arsenic, phenols, detergents) and the possible causes have been identified. The majority of determinants/pollutants have a tendency towards the improvement of water quality due to the closing of many industrial and agricultural sources of pollution, the reduction in the intensity of agriculture (a reduction in the number of animals and chemical fertilizers used), the reduction of the number and magnitude of accidental pollutions and measures taken for reduction of pollution by construction of wastewater treatment plants for urban agglomerations and industrial installations, the application of the best available technologies in industry and the best practices in agriculture, and the use of phosphorus free detergents in accordance to the national and European legislation.

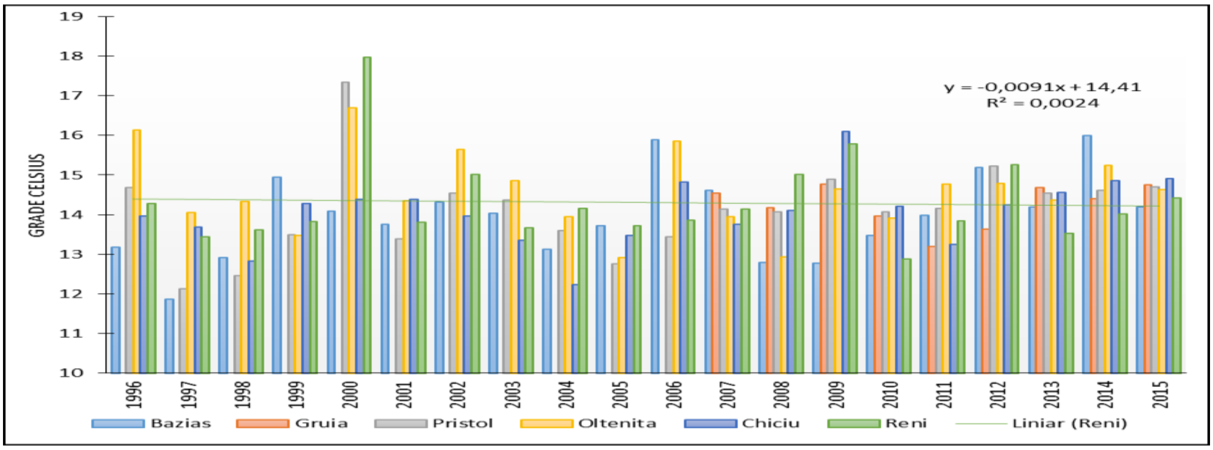

Figure 3.1. Variation of water temperature annual average values (1996-2015)

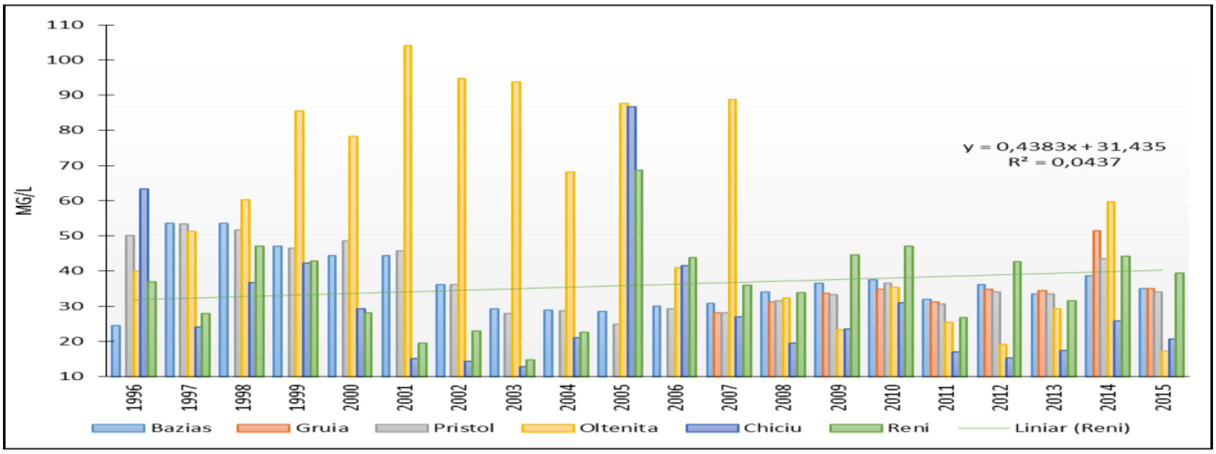

Figure 3.2. Variation of suspended solids concentrations annual average values (1996-2015)

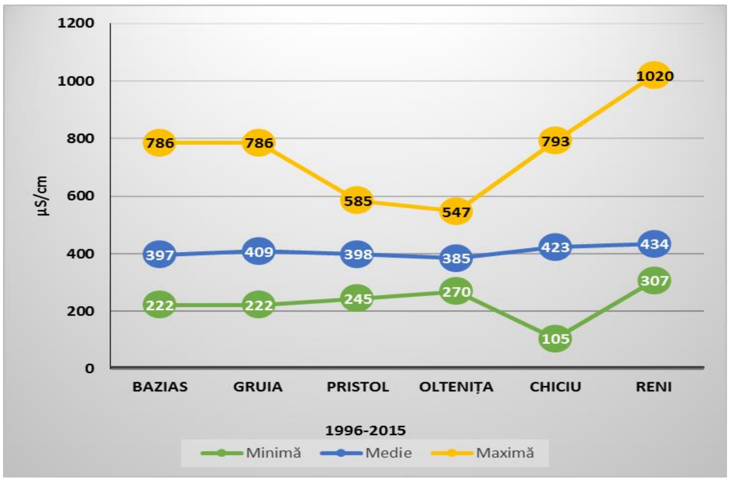

Figure 3.3. Variation of minimum, average and maximum multiannual values of water conductivity (1996-2015)

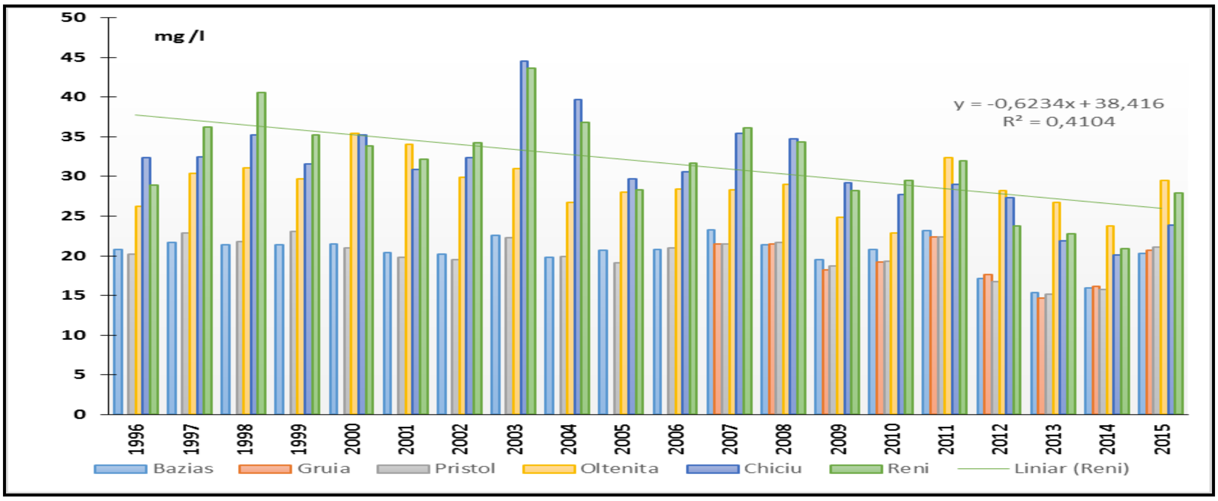

Figure 3.4. Variation of chlorides concentrations annual average values (1996-2015)

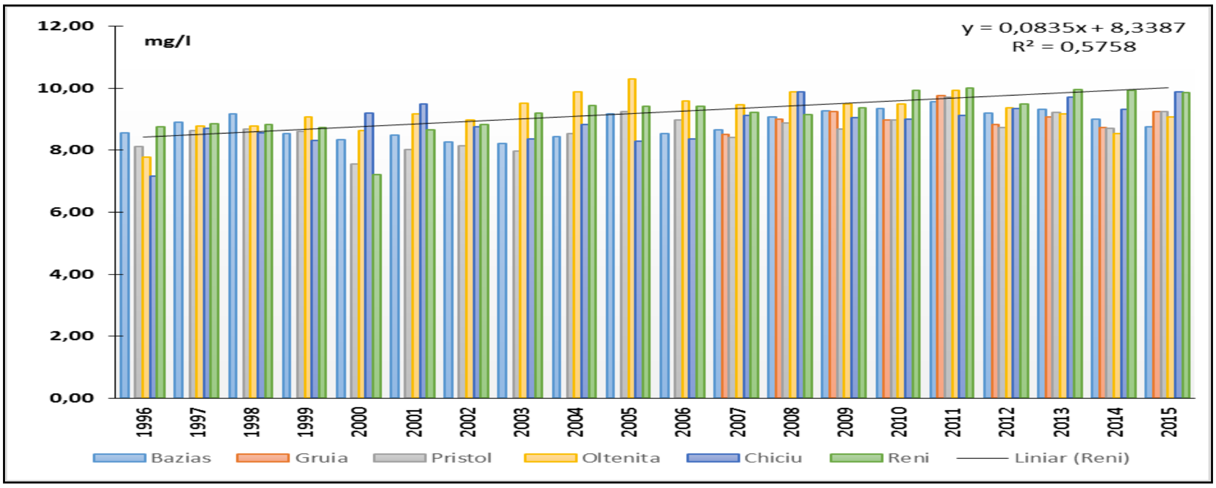

Figure 3.5. Variation of dissolved oxygen concentrations annual average values (1996-2015)

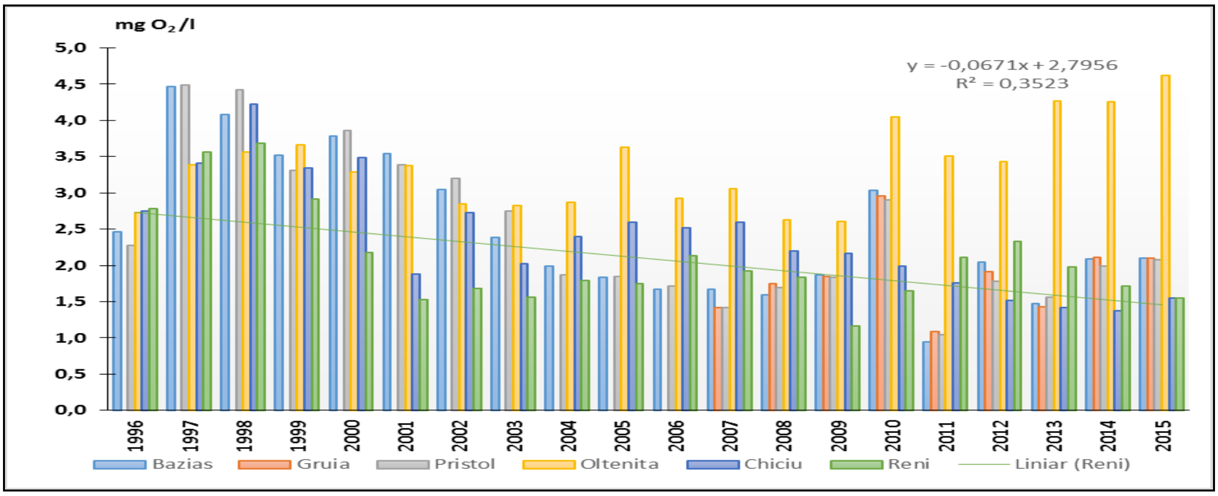

Figure 3.6. Variation of BOD_5 concentrations annual average values (1996-2015)

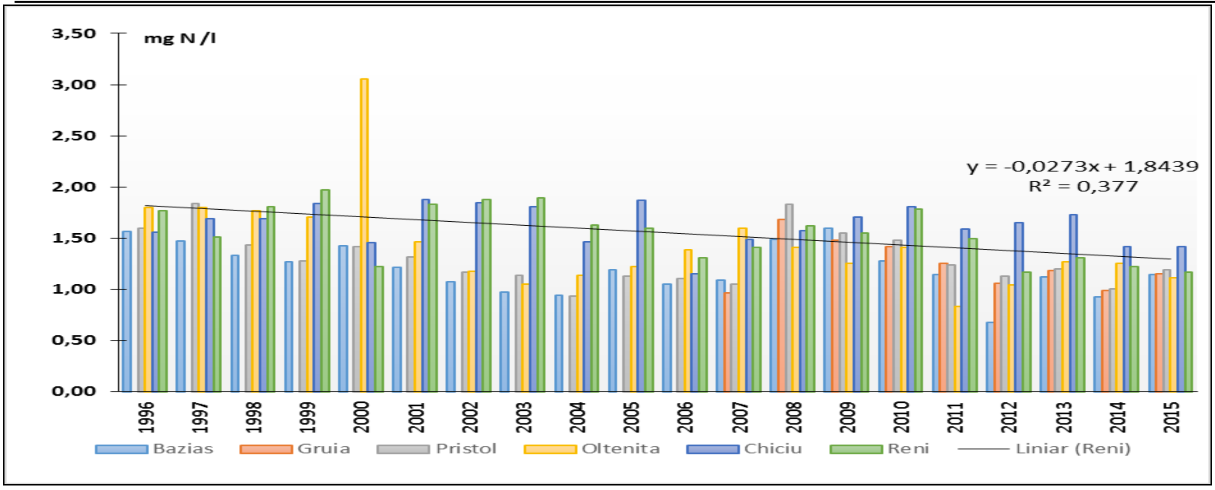

Figure 3.7. Variation of N-nitrates concentrations annual average values (1996-2015)

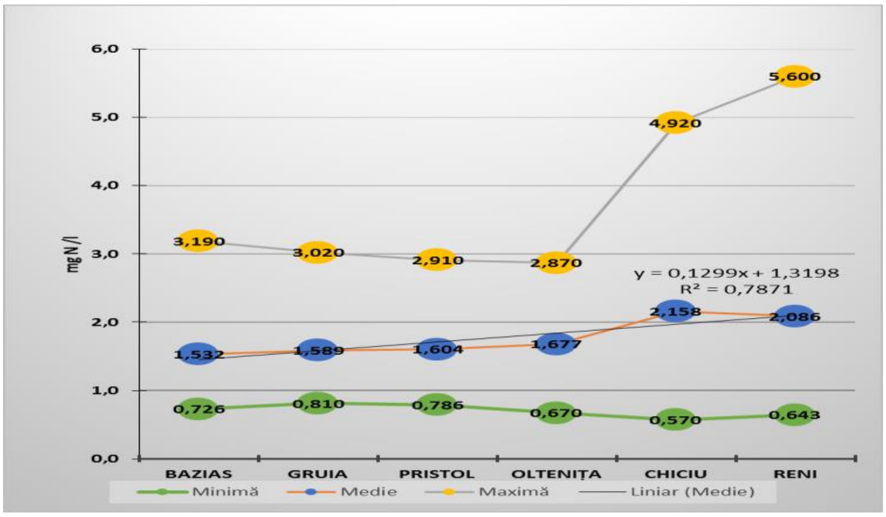

Figure 3.8. Variation of minimum, average and maximum multiannual values of Ntotal (2003-2015)

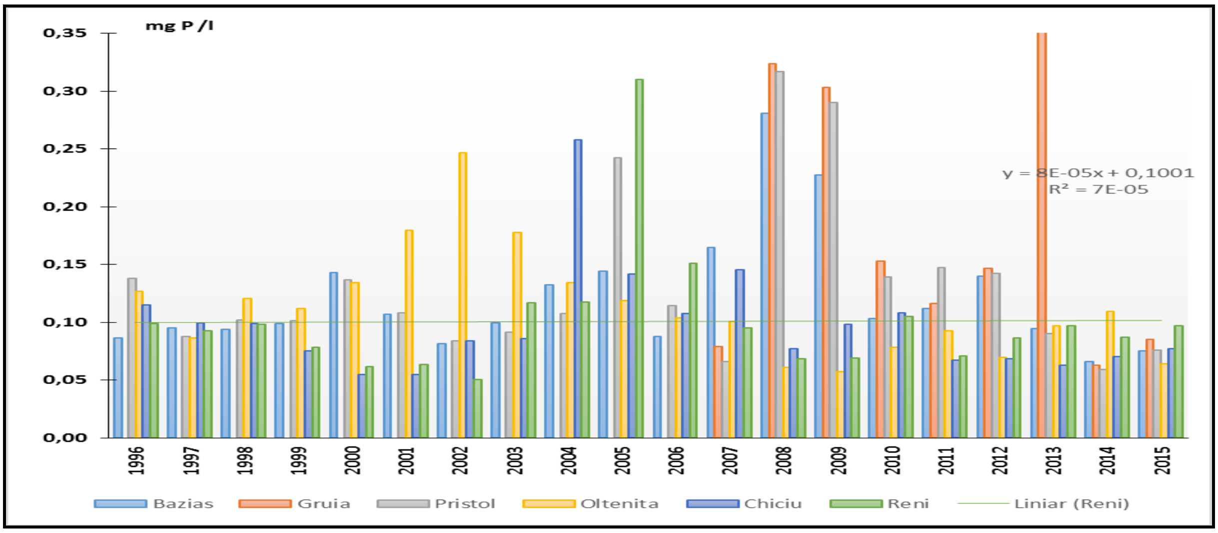

Figure 3.9. Variation of Ptotal concentrations annual average values (1996-2015)

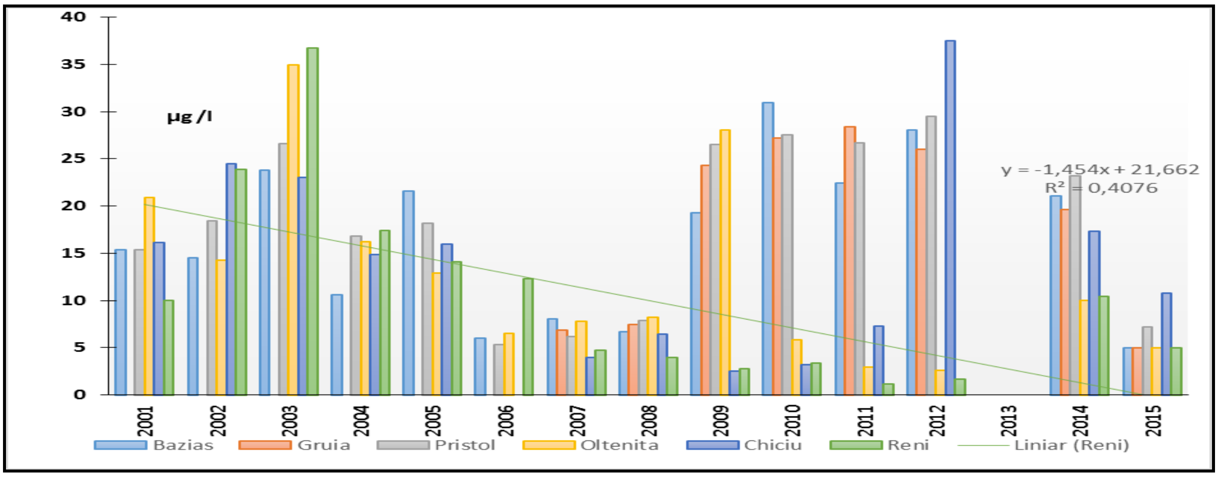

Figure 3.10. Variation of dissolved zinc concentrations annual average values (2001-2015)

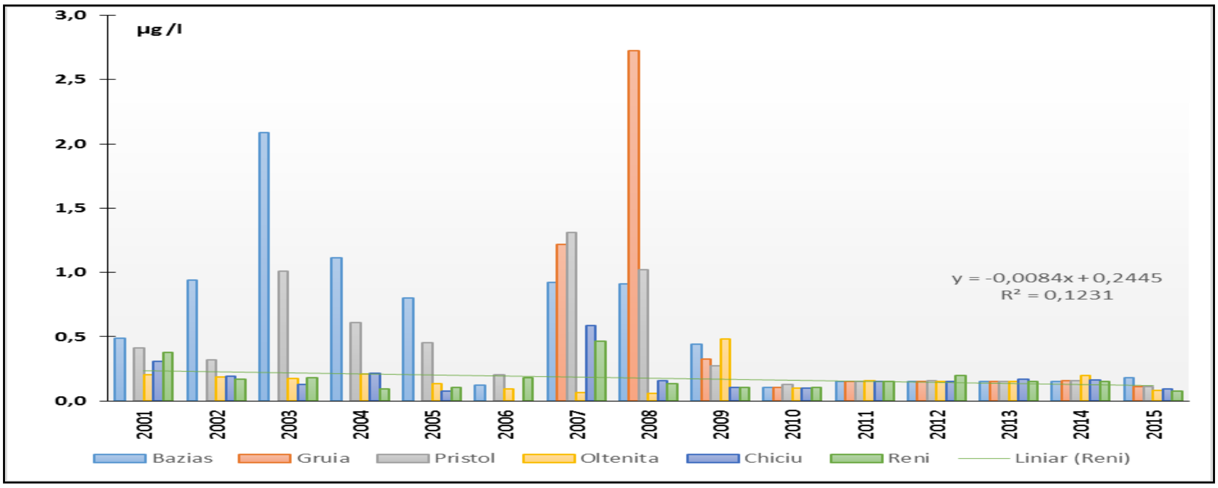

Figure 3.11. Variation of dissolved cadmium concentrations annual average values (2001-2015)

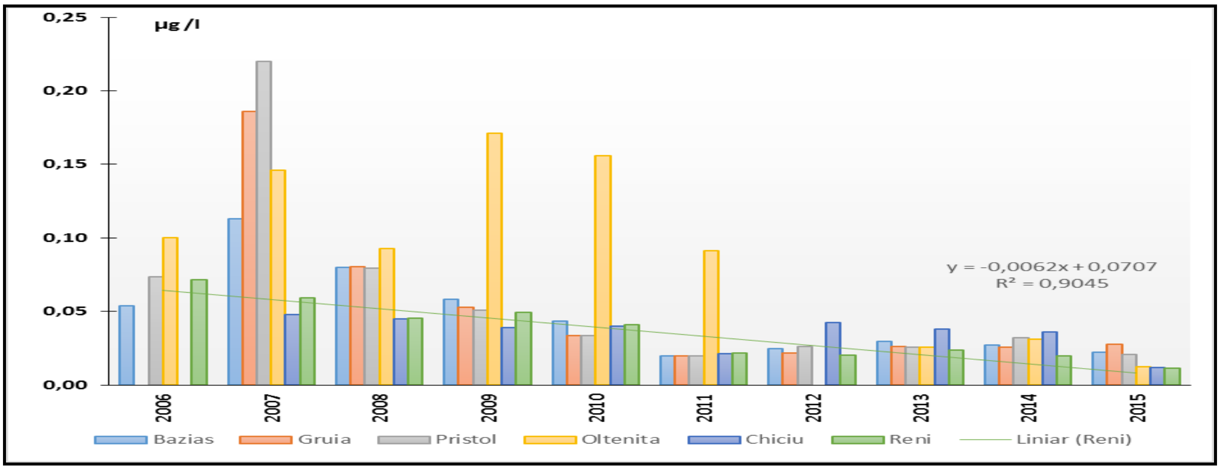

Figure 3.12. Variation of dissolved mercury concentrations annual average values (2006-2015)

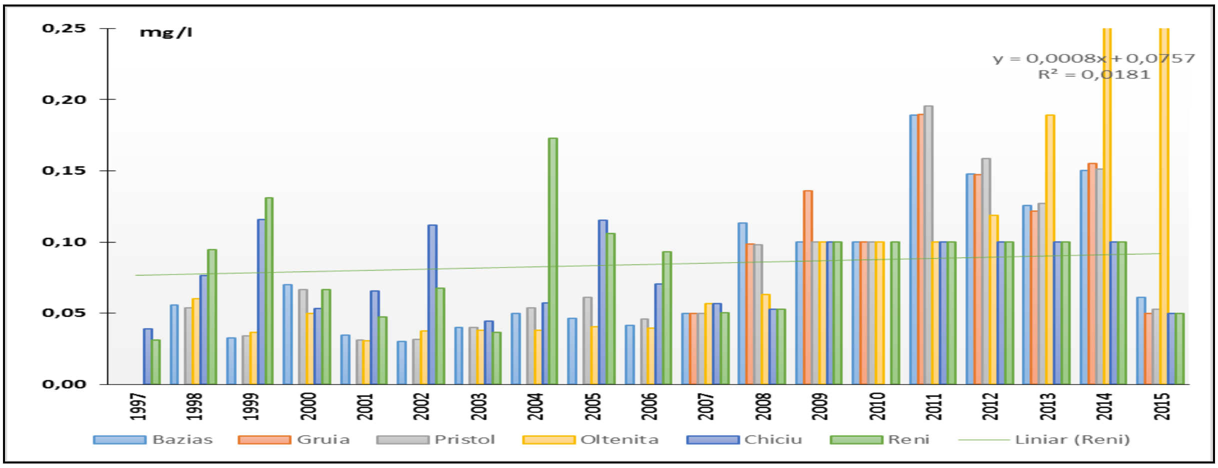

Figure 3.13. Variation of anion active detergents concentrations annual average values (1997-2015)

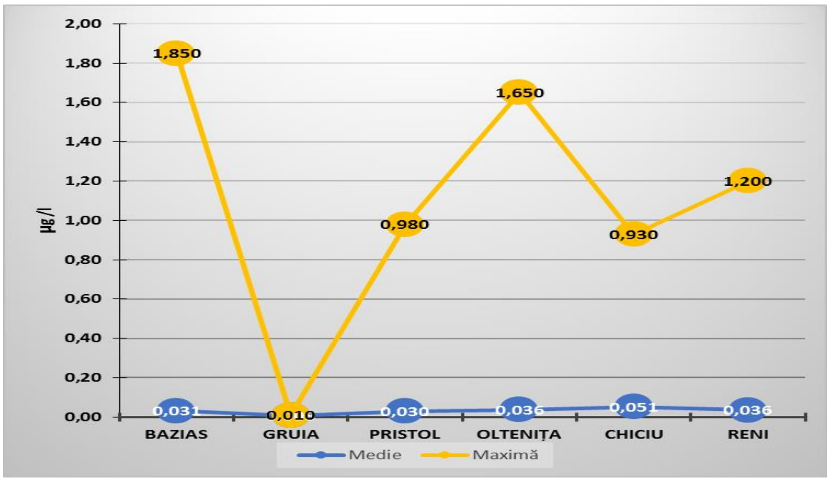

Figure 3.14. Variation of minimum, average and maximum multiannual values of pp'DDT (1996-2015)

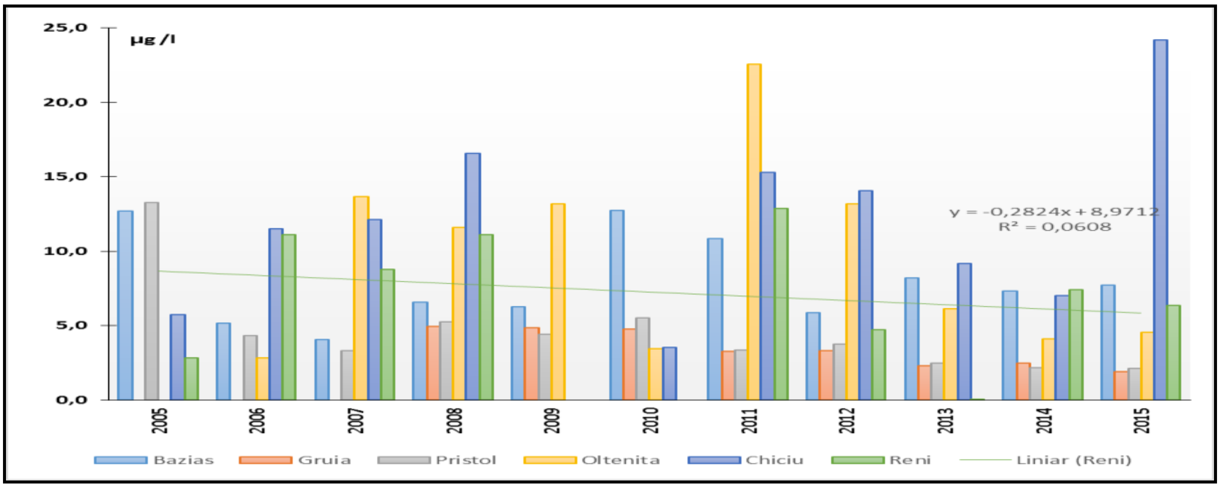

Figure 3.15. Variation of phytoplankton – chlorophyll a biomass concentrations annual average values (2005-2015)

4. CORRELATION OF WATER QUALITY WITH HYDROLOGICAL CHARACTERISTICS IN THE DANUBE RIVER LOWER SECTOR

4.1. Methodological aspects

In chapter 4, the primary objective is the research/analysis of the dependency of qualitative aspects (physico-chemical parameters) with quantitative aspects, respective the flow regime in three monitoring sites (Pristol, Chiciu, Reni). The analysis of the variability of physico-chemical parameters with the hydrological regime was analyzed through correlating the flow with both the determinant/pollutant loads that are transported by the Danube River and their concentrations (table 4.1).

Table 4.1. Monitoring sites/gauging stations and physico-chemical and hydrological determinants/parameters

Qualitative monitoring site and location	Gauging station and location	Physico-chemical determinants and the parameters of the hydrological regime
Pristol, km 834	Gruia, km 856,5	Annual average loads and concentrations for *suspended solids; chlorides; BOD_5; inorganic nitrogen; phosphorus from ortho-phosphates and total phosphorus/ annual average flow* for the period between 2006 and 2015
Chiciu, km 375	Chiciu- Călărași km 379,6	Annual average loads and concentrations for *suspended solids; chlorides; BOD_5; inorganic nitrogen; phosphorus from ortho-phosphates and total phosphorus/ annual average flow* for the period between 2006 and 2015
Reni, km 132	Isaccea km 100,2	Annual average loads and concentrations for *suspended solids; chlorides; BOD_5; inorganic nitrogen and total nitrogen; nitrogen from nitrates, nitrites and ammonium phosphorus from ortho-phosphates and total phosphorus; dissolved copper and total copper; dissolved lead and total lead; dissolved cadmium and total cadmium; dissolved mercury and total mercury/ annual average flow* for the period between 2007 and 2016

		• Daily concentrations of *suspended matter, chlorides, BOD_5, total nitrogen and nitrogen from nitrates; phosphorus from ortho-phosphates and total phosphorus; dissolved copper and total copper; dissolved lead and total lead; dissolved cadmium and total cadmium; dissolved mercury and total mercury /daily average flow* for years 2010 (high water) and 2012 (low water)

4.2. Results and interpretations

Taking into consideration the results of the analysis of correlation between the flow and the loads and concentrations of suspended solids, chlorides, organic matter (BOD_5), nutrients (nitrogen and phosphorus forms in the state of dissolved salts – nitrates, nitrites, ammonium, ortho-phosphates, to which total nitrogen and phosphorus is added), and heavy metals, the following conclusions have been drawn:

- A good correlation (direct proportionality) has been found between annual average flows and the annual average loads of determinants, for all parameters/pollutants (figures 4.1, 4.4, 4.7), with the exception of heavy metals where a partial correlation exists for mercury and lead (figure 4.10), and a clear dependency for copper and cadmium has not been proven;
- The analysis of the variability of annual average concentrations in correlation with the annual average flow has led to good results for suspended solids (figure 4.2) and nitrogen forms (total nitrogen, inorganic nitrogen, nitrates). In addition, a smaller dependency was observed for chlorides, BOD_5 (figure 4.5), ammonium, and phosphorus forms (figure 4.8). For heavy metals, it can be shown that the hydrological regime of 2010 caused a dilution, with smaller concentrations of copper, cadmium and lead found in the water (figure 4.11);
- The analysis of the variability of momentary concentrations with the daily average flow at Reni monitoring site in 2 years that are different from hydrological regime point of view has emphasized a partial correlation, especially during low water for suspended solids (figure 4.3), BOD_5 (figure 4.6), total nitrogen and ortho-phosphates (figure 4.9);

- There are behavioural differences between dissolved substances and substances that can be found in adsorbed on suspended solids or on sediments, in the sense that the latter are more dependent on the concentration of suspended solids than they are on liquid flow.

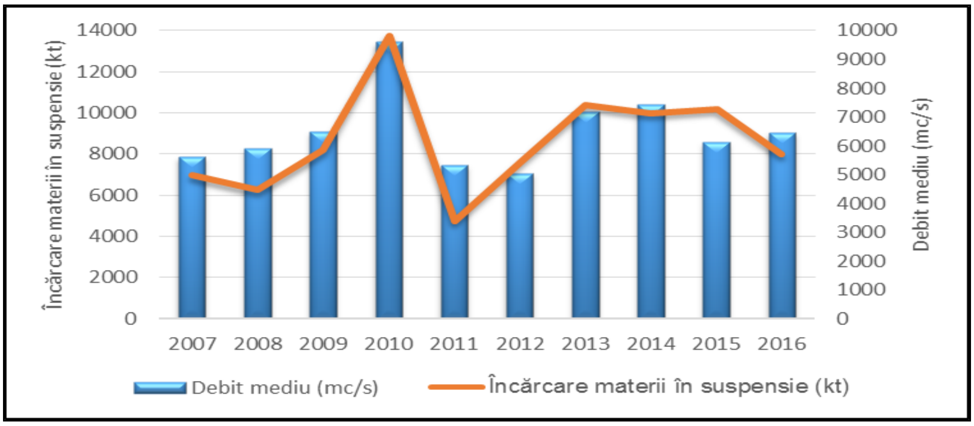

Figure 4.1. Variation of suspended solids loads with average flow in Reni monitoring site (2007-2016)

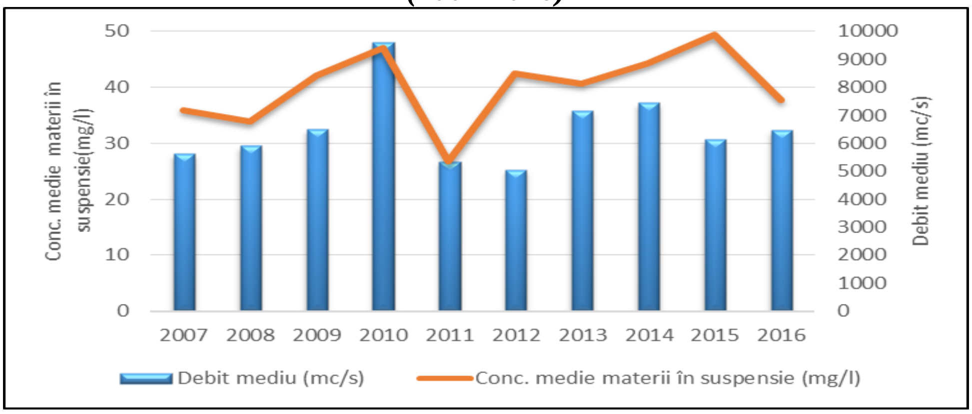

Figure 4.2. Variation of suspended solids average concentrations with average flow in Reni monitoring site (2007-2016)

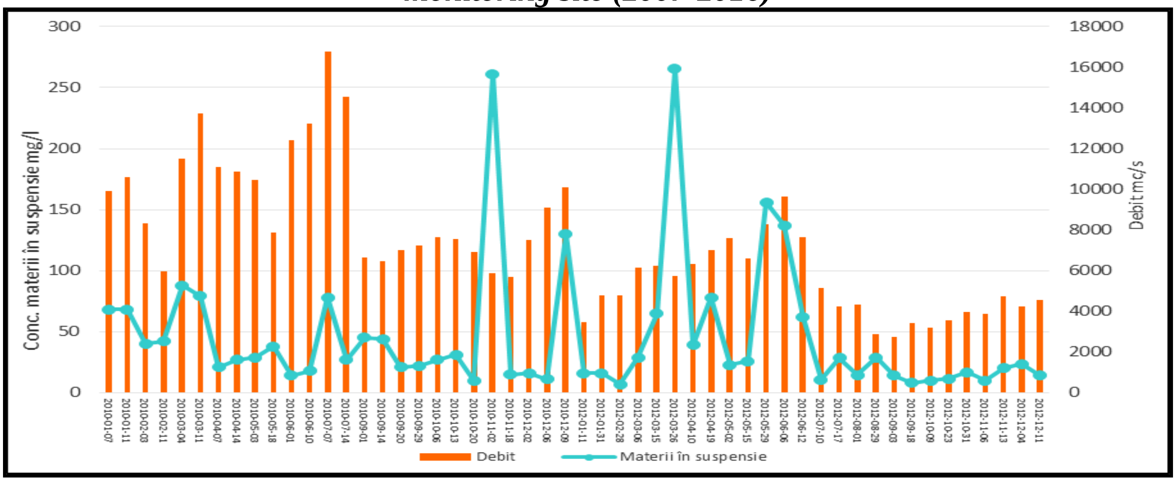

Figure 4.3. Variation of suspended solids concentrations with flow in Reni monitoring site (2010 and 2012)

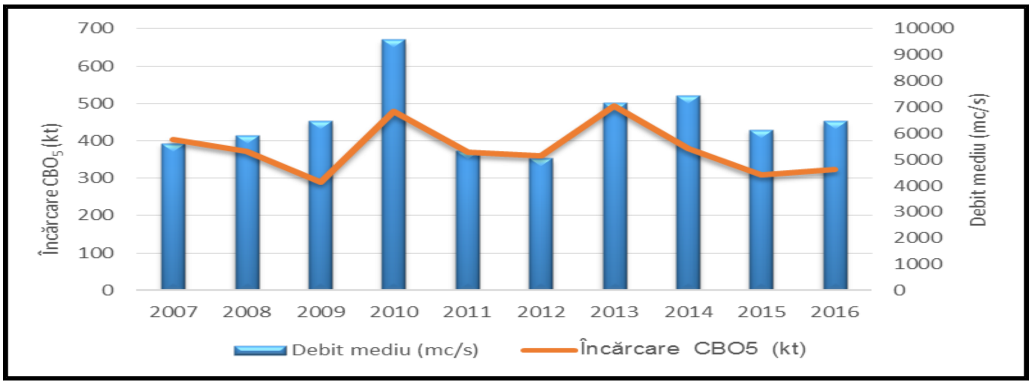

Figure 4.4. Variation of BOD_5 loads with average flow in Reni monitoring site (2007-2015)

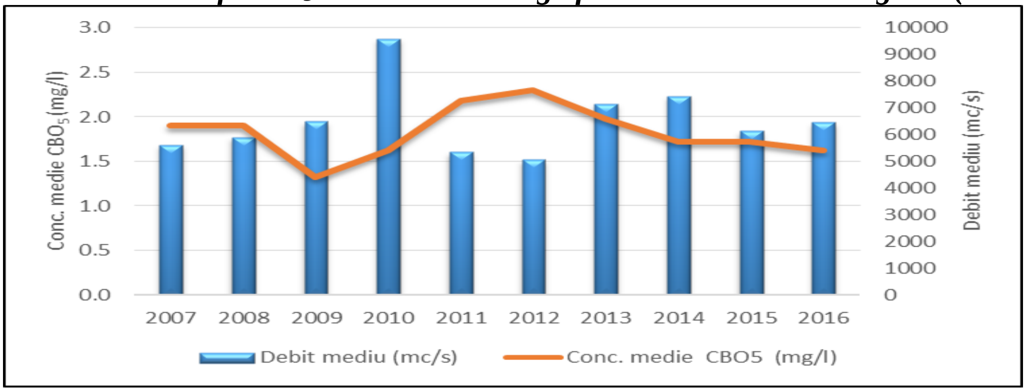

Figure 4.5. Variation of BOD_5 average concentrations with average flow in Reni monitoring site (2007-2016)

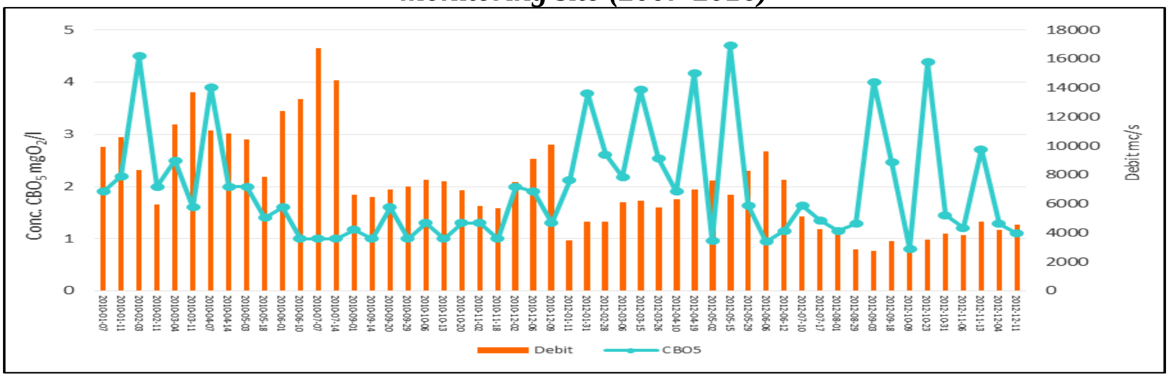

Figure 4.6. Variation of BOD_5 concentrations with flow in Reni monitoring site (2010 and 2012)

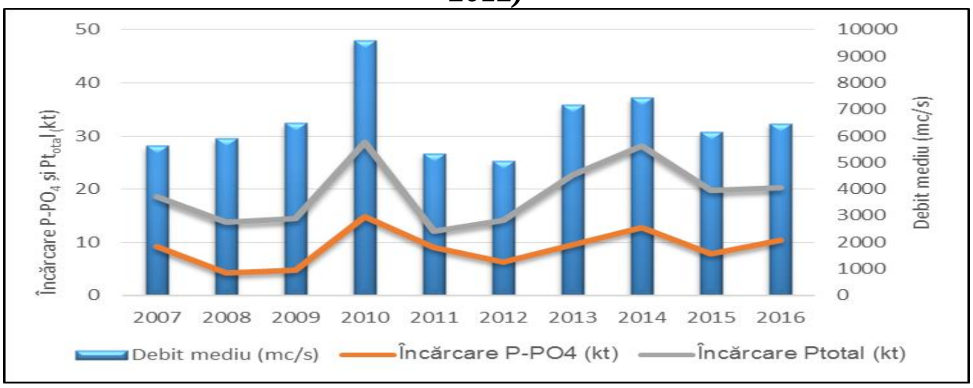

Figure 4.7. Variation of P-orthophosphates and Ptotal loads with average flow in Reni monitoring site (2007-2016)

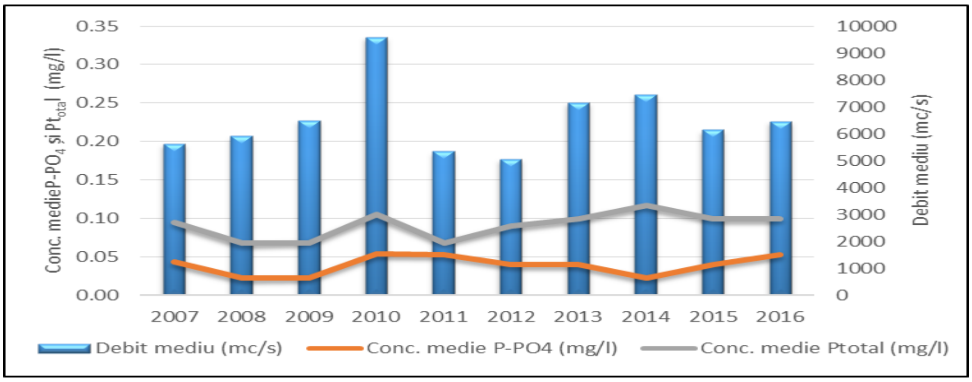

Figure 4.8. Variation of P-orthophosphates and Ptotal average concentrations with average flow in Reni monitoring site (2007-2016)

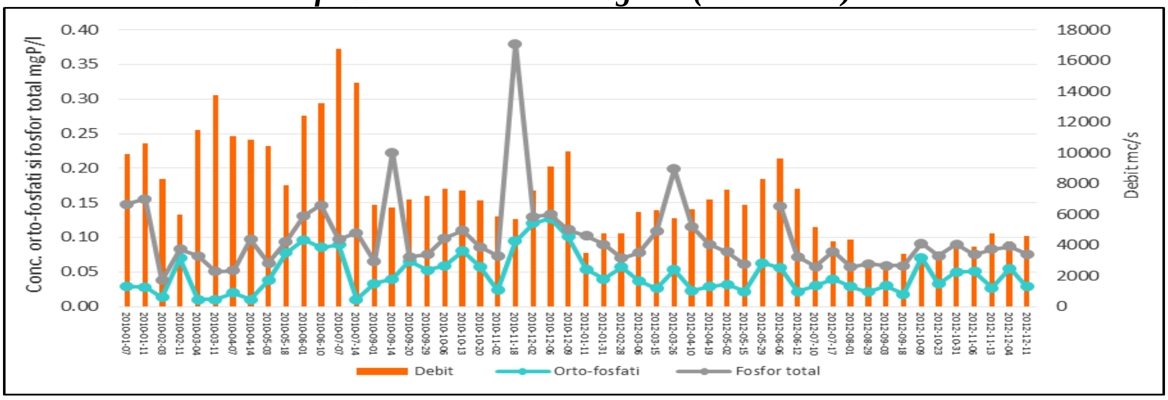

Figura 4.9. Variation of P-orthophosphates and Ptotal concentrations with flow in Reni monitoring site (2010 and 2012)

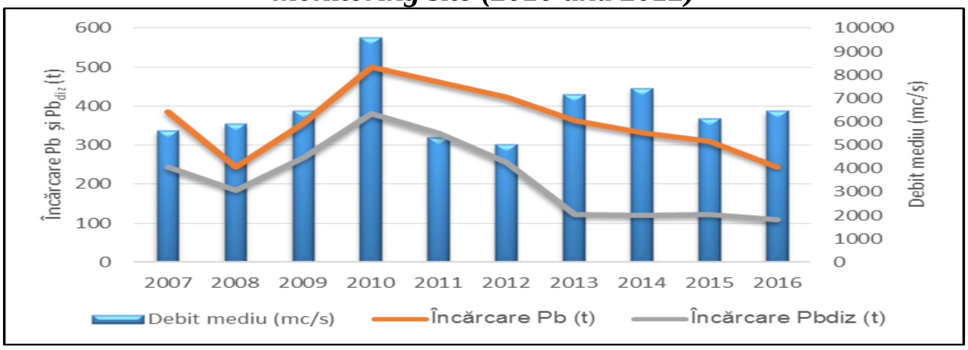

Figure 4.10. Variation of total Lead and dissolved Lead loads with average flow in Reni monitoring site (2007-2016)

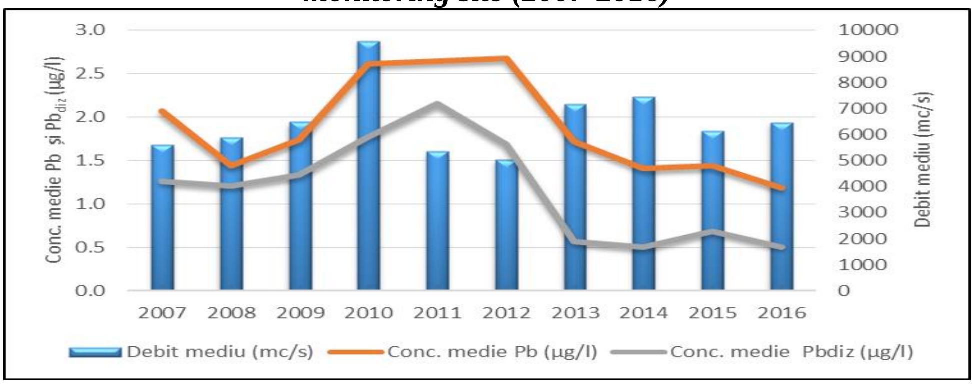

Figure 4.11. Variation of total Lead and dissolved Lead average concentrations with average flow in Reni monitoring site (2007-2016)

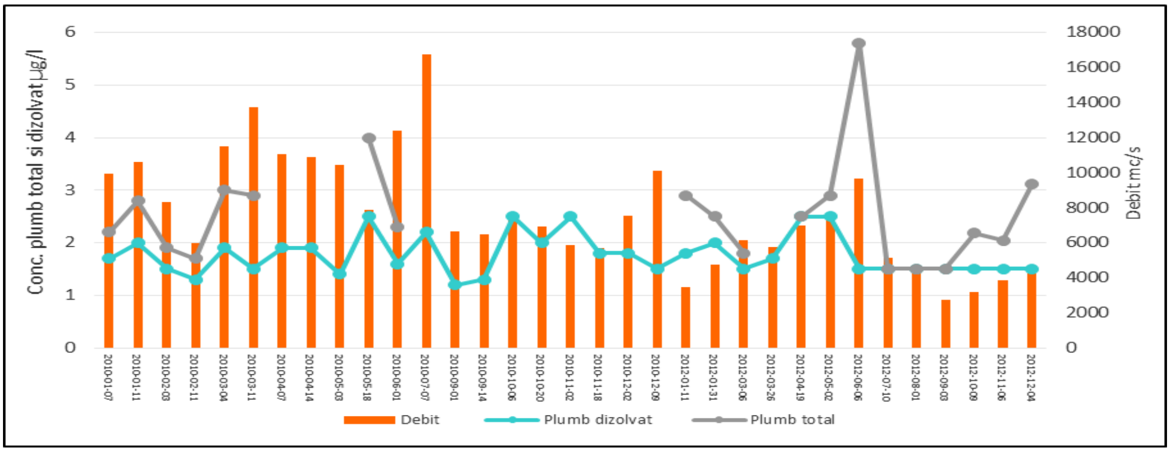

Figure 4.12. Variation of total Lead and dissolved Lead concentrations with flow in Reni monitoring site (2010 și 2012)

In some situations, the correlation could not be shown for all determinants and for the entire analysed period due to other factors such as:

- presence of pollution sources in the vicinity of analysed monitoring sites;
- contribution of tributaries (especially the Argeș, Siret, and Prut rivers);
- effect of pollution reduction measures which have especially had an effect during the last 5 years;
- presence of some determinants, especially heavy metals in very small concentrations, close to the limit of quantification or even less than it (e.g. cadmium and mercury with concentrations between 10^{-5} and 10^{-3} mg/l).

5. IMPACT OF CLIMATE CHANGES ON THE WATER QUALITY OF THE DANUBE RIVER LOWER SECTOR

5.1. Introductory aspects

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

From the point of view of the hydrological regime, climate changes are predicted to alter availability, seasonal variation and flow variability. The variation of water temperature affects the physico-chemical, biological and microbiological balances. From the physico-chemical perspective, the natural processes are affected, especially nitrification-denitrification, mineralization of organic matter with changes of pollutant concentrations and loads transported by rivers.

5.2. Aspects relevant to the lower Danube River Basin and Romania

In the Danube River Basin, the study regarding adaptations to climate change undergone between 2010 and 2012 (Danube Study – Climate Change Adaptation) by the Ludwig Maximilians University in Munchen, Germany, as well as Technical Reports developed by the Joint Research Centre – Water scenarios for the Danube River Basin (JRC Technical Reports - Water Scenarios for the Danube River Basin, 2016) have shown that the air temperature will rise in the Danube River Basin by one degree in the NW part towards SE (for the period between 2030 – 2050), by over a gradient in the E and SE part of the basin (JRC, 2017). In regards to Romania, the temperature during summer will increase by 1.8 – 2.1°C and by 1.4 – 1.51°C during winter in the period 2021 - 2050.

From rainfall point of view, it is expected that the annual average precipitations will follow a decreasing trend, with changes in seasonal precipitations, such as smaller quantities of rainfall during summer (25 – 45% less) and a slight increase or stability for winter. Thus it is forecast that the annual average precipitation quantities will decrease by around 5 to 15% in Romania. The annual average flow of the lower Danube Basin will decrease by 5-20%, due to the excessive decrease during the summer. It is possible that the risk of flooding and the frequency of floods may increase, especially flash floods, but the risk for seasonal early spring flooding may decrease due to the reduction of snow (Danube River Basin Study on Climate Change Adaptation, 2012).

In Romania, in the framework of research study ADER – *A system of geo-referential indicators on various spatial and temporal scales for the evaluation of vulnerability and adaptive measures of agroecosystems toward global changes* (2011-2014), the Meteorological National Administration (ANM) developed climatic scenarios for the 21st century and estimated effects on multiannual average temperatures, as well as multiannual average precipitations in Romania.

5.3. Research on the climate changes effects on the water quality of the Danube River lower sector

As it has been underlined in previous sub-chapters, the hydrological regime and water temperature rule the physico-chemical processes in the aquatic environment. Both the hydrological regime and water temperature, but especially their season variability are influenced by global warming. In this context, the study developed in this sub-chapter endeavoured to outline the effects of climate changes on water quality in a representative monitoring site, respective Reni section (km 132), middle profile. From the physico-chemical point of view, the studied parameters are: water temperature, dissolved oxygen, BOD_5, nitrates, ammonium, nitrites and ortho-phosphates.

The limitations of this multiannual analysis on the lower sector of the Danube River are: the relatively short studied period (from global changes perspective), as well as the impossibility of separating only climate changes from other factors, such as the variability of anthropogenic pressures and the effect of measures taken for the improvement of water quality.

- ***The analysis of multiannual variation of the physico-chemical parameter concentrations and water temperature***

For the analysed period, the correlation/dependency between the variation of water temperature and the variation of dissolved oxygen, BOD_5, nitrates, ammonium, nitrites and ortho-phosphates concentrations was studied. The analysis of the multiannual variation of physico-chemical parameters (thermal conditions, oxygenation conditions and nutrients regime) for the period 1996 - 2014 shows an increasing linear temporal trend for dissolved oxygen (figure 5.1) and ortho-phosphates (figure 5.4) and a decreasing trend for organic biodegradable matter (figure 5.2) and inorganic nitrogen compounds (figure 5.3).

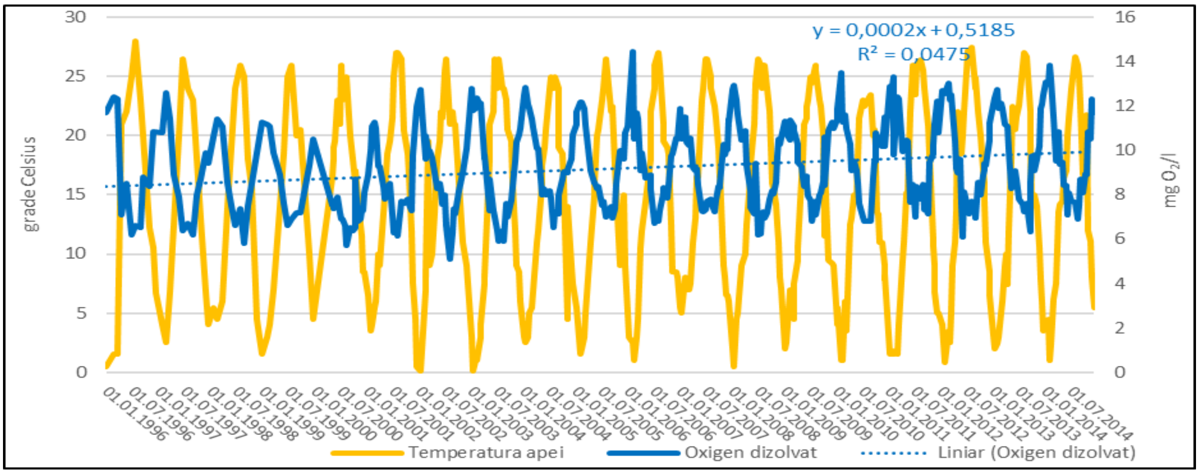

Figure 5.1. Variation of oxygen dissolved concentration with water temperature in Reni monitoring site

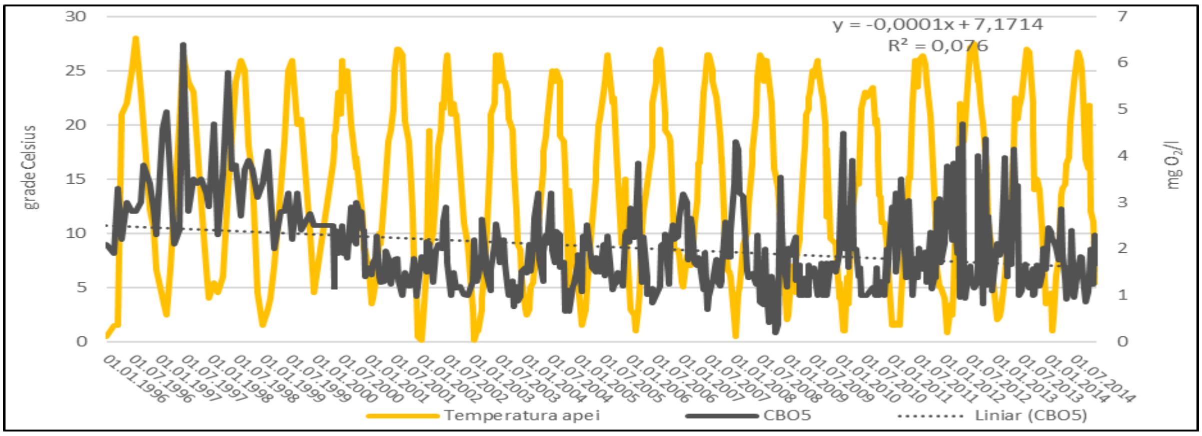

Figure 5.2. Variation of BOD_5 concentration with water temperature in Reni monitoring site

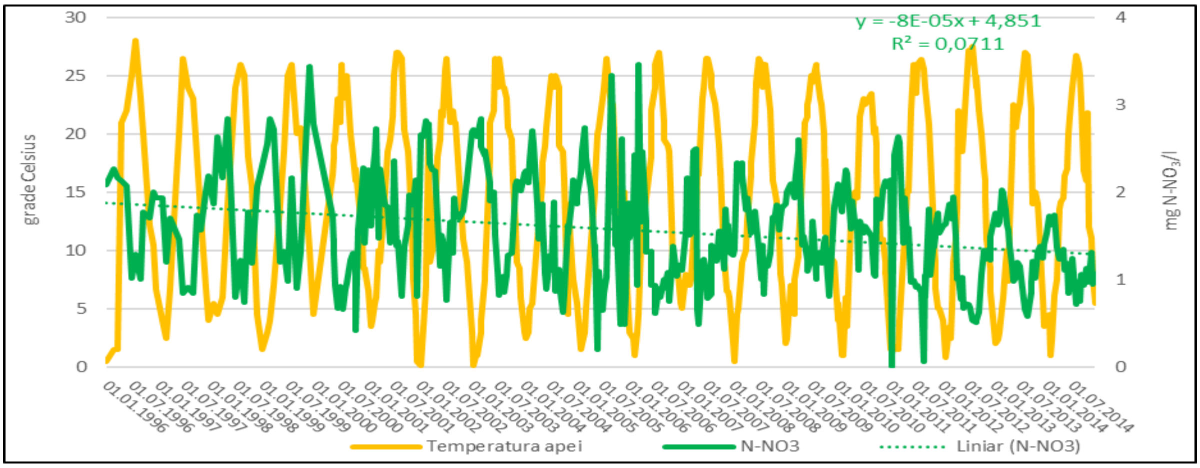

Figure 5.3. Variation of N-NO_3 concentration with water temperature in Reni monitoring site

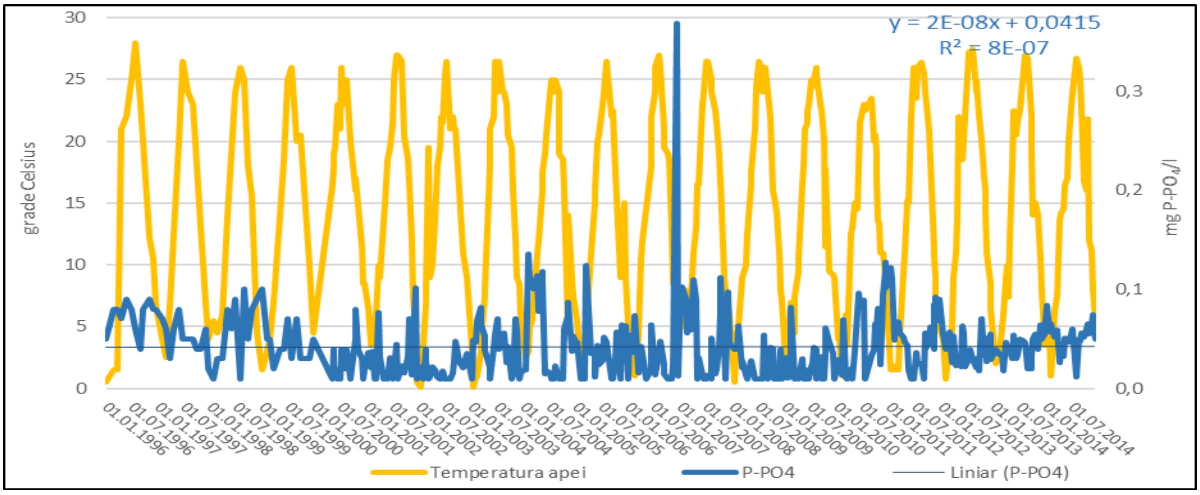

Figure 5.4. Variation of P-PO₄ concentration with water temperature in Reni monitoring site

- ***The analysis of multiannual monthly variation of physico-chemical parameter concentrations and water temperature***

For a more detailed analysis on the possible impact of global warming on the temporal and seasonal variation of physico-chemical parameters concentrations, this variation and the correlation between parameters at the level of *each month (January to December)* has been studied *for the period 1996-2014* in the Reni monitoring site, middle profile (table 5.1).

Regarding the *water temperature,* a decreasing trend can be observed for the months January - July and an increasing trend can be observed for the months 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 which exceeds the possible impact of the increase of the water temperature corresponding to the months of August - December.

The multiannual monthly variation of *biodegradable organic substances (BOD_5)* concentrations show an increasing trend for the majority of months, with the exception of months Feburary – April and September, which show a decreasing trend. The decrease shown in months February - April can be explained through increasing of flow and dilution of organic substances loads in the large water volume.

Table 5.1. Multiannual linear tendency of physico-chemical parameters concentrations monthly values in Reni monitoring site

Month	**Linear multiannual tendency 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	↑	↑	↑	↓	↓	↓	↑

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

In regards to multiannual monthly concentrations of *nitrogen from ammonium*, an increasing trend can be observed during the first 6 months (with the exception of February), correlated with the presence of runoff from soils which are rich in nitrate compounds (from natural and chemical fertilizers) taking place during the spring and the beginning of summer, as well as a correlation with the water temperature variation with a decreasing trend which do not support the nitrification processes. On the contrary, in the months with a decreasing trend of ammonium nitrogen concentrations, respectively July-August and November-December, shows a possible concentration related to the reduced flows during the summer period, as well as the effect of the increase of the water temperature in the months of November - December of the analyzed period which led to increase the rate of nitrification.

Nitrogen from nitrites concentrations vary on a multiannual monthly level similar to ammonium nitrogen. With the exception of February, May, October and November, in general it has a multiannual increasing trend in the first 6 months and a decreasing trend in the last 6 months of the year. The tendencies accurately correlate with the water temperature variation (the increase of water temperature catalyse nitrification processes).

In regards to the multiannual monthly trend of *phosphorus from ortho-phosphates* concentrations, a decreasing trend can be observed for the majority of months, especially during warm months (the period between May and August) which shows the consumption of ortho-phosphates in algal blooms (phytoplankton production). In addition, a multiannual increasing trend has been shown during the months of spring (March - April), autumn and beginning of winter (September, November, December) due to precipitations and the drainage and washing of soils containing phosphorus.

- ***Variation analysis on the concentrations of chemical parameters with the monthly average flow during years 2003 and 2006***

In this sub-chapter, the effect on water quality of the variation of monthly average flow at Isaccea monitoring station is analysed for years 2003 and 2006, two years that differ greatly from hydrological point of view. The variation range of flow on both annual and multiannual levels across the two years may be due to global climate change.

From a hydrological point of view, in **2003** the Danube flows in the Isaccea gauging station were above the monthly average values in January and February and below them in the other months, the lowest values being registered during July - September when they were below 50% of the normal monthly values. The year 2003 was characterized by an annual mean flow of 5030 m^3/s in Isaccea, approx. 30% under the multiannual average. In regards to the hydrological evolution of the Danube River, the year **2006** marked an exceptional flood in months April - May, the largest flood registered on the lower sector of the Danube River in the last 100 years both regarding the maximum flows registered and the period during which water levels remained over flood levels. The year 2006 was characterized by an annual average flow of approx. 8310 m^3/s registered at the Isaccea station on the lower course of the Danube River, exceeding multiannual average flows by 30%. Between March and June, average monthly flows varied in the range of 10,800 – 15,100 m^3/s, with a high average flow rate, but less than 10,000 m^3/s in July.

Considering the different characteristics of the period of July - September of 2003 comparative with the period of March - June of 2006, with extremely high monthly average flows, the multiannual average values (2001-2010) of chemical indicators (oxygenation regime: dissolved oxygen, BOD_5, and nutrients: $N\text{-}NO_3$, $N\text{-}NH_4$, $N\text{-}NO_2$, $P\text{-}PO_4$) were compared with annual average values during each year 2003 and 2006, as well as the average values of decade with the average values of the two extreme periods.

In regards to the year 2003, *higher values of BOD_5 and $P\text{-}PO_4$* were registered, as well as *lower values of dissolved oxygen* for the averages during the low flow period compared to the 2003 average and the decade average. In regards to dissolved oxygen, the lower values are justified through the decrease in flow and the increase of water temperature and biodegradable substances concentrations registered in 2003 during the period between July and September. Regarding the nitrogen forms, their concentrations are lower during the period of low waters, being explained by the increase of the nitrification rate and by the algal growth with the consumption of mineral nitrogen.

Concerning the year 2006, *higher values of $N\text{-}NO_3$ and $N\text{-}NO_2$* were registered for averages during the period of high/extreme flow, compared to the average of the year 2006 and the decade average. $N\text{-}NH_4$ concentrations corresponding to the high water periods register much higher values than the decade average. In regards to dissolved oxygen, higher values are justified through the increase of flow and discharge characteristics, as well as the fall of biodegradable organic substance concentrations registered during March - June 2006. 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. The decrease of the $P\text{-}PO_4$ concentrations during high water periods is due to dilution.

6. WATER MANAGEMENT IN THE CONTEXT OF ACHIEVING AND MAINTAINING GOOD WATER STATUS

6.1. European and national legal provisions

The European policy in regards to the water field is based on the provisions of the *Water Framework Directive (2000/60/EC), the Directive on the assessment and management of flood risks (2007/60/EC) and the Marine Strategy Framework Directive (2008/56/EC).*

The Water Framework Directive's main objective is *the achievement and maintenance of good water status* for all water categories named water bodies (**surface waters** – lakes, rivers, transitional and coastal waters and **groundwaters**) by 2015 and, through the application of exceptions, by 2021 and 2027 through the establishment an implementation of measures for the reduction of water pollution and the mitigation of anthropogenic pressures effects including hydromorphological alterations.

Also, the Water Framework Directive foresees the achievement of environmental objectives based on cyclical planning, so once every 6 years from 2009, a river basin management plan should be developed / updated.

The Management Plan underlies measures for the protection of surface and ground water, taking into consideration the following: achieving and maintaining good water status, as well as preventing its subsequent deterioration, the promotion of sustainable use of water, the progressive reduction of discharges, emissions and losses of priority substances, the phasing out discharges, emissions and losses of hazardous priority substances and the progressive reduction of groundwater pollution and the prevention of its subsequent pollution.

6.2. Stage of Water Framework Directive implementation in Romania

According to the *Water Law 107/1996* with its subsequent amendments and completions, the *River Basin Management and Development Scheme* is the planning tool in the water field, being composed by the *Management Plan and the Development Plan*. The River Basin/District Management Plan is the instrument that ensures the qualitative management of water resources, which the competent authorities (Ministry of Waters and Forests and National Administration "Romanian Waters") should elaborate and update periodically (6 years).

The planning process has begun in period 2003-2004 with the transposition and administrative steps, followed by the characterization of river basins (2004-2005), the setting water monitoring programs (2006-2007), the evaluation of water status, the setting objectives, as well as the development of measures program (2008-2009) and measures implementation (2010-2015).

The National Management Plan – the synthesis of the *11 River Basin Management Plans* was developed until the 22nd of December 2009 and approved through GD no. 80/2011. The content of the Management Plan followed the provisions of the Annex VII of the Water Framework Directive. The second planning cycle followed the same steps and strategic approach, thus, the *updated National Management Plan* (scheduled to be implemented 2016-2021) was finalized at the end of 2015 and approved through GD no. 859/2016.

7. CARACTERISATION OF THE WATER BODIES ON THE DANUBE RIVER BETWEEN BAZIAȘ AND ISACCEA

7.1. Water bodies' typology

Surface water typology is a concept introduced by the Water Framework Directive which implies the development of a classification inside each water body category based on criteria characteristic of natural conditions. A ***type of surface water*** (river, lake, transitional water, coastal water) is a unit delineated on certain criteria, having in its natural condition a biotic and abiotic variation specific to respective type. Surface water typology is a classification in types which have an aquatic flora and fauna which is characteristic to natural morphological, geological and climatic conditions (antropogenically significant non-altered).

The Danube typology was defined at the international level, being developed and harmonised through the GEF/UNDP Danube Regional Project – *The typology and reference conditions for the Danube River.* For the lower course of the Danube River (between Baziaș and Isaccea), *3 types* have been delineated (RO12 – Dunărea Cazane, RO13 – Dunărea Cazane – Călărași, RO14 – Dunărea Călărași - Isaccea). Considering that two dams with reservoirs have been built on the Danube River (Iron Gates and Ostrovul Mare), on this sector there has been defined a reservoir typology (ROLA03 – reservoir in plain area, big depth, siliceous geology).

7.2. Water bodies' delineation

The water body concept is introduced by the Water Framework Directive, defined in the article 2 as *"discrete and significant element of surface waters such as: river, lake, canal,* *river sector, canal sector, transitional waters, part of coastal waters".* The definition of the water body can be practically translated through the dividing the hydrographical network in continuous and homogenous elements, both from hydrological, morphological and ecological point of view, as well as from the perspective of anthropogenic pressures and water status.

More concretely, the process of water body delineation entails a spatial analysis made through the overlapping of multiple informational levels, considering *the surface water category, the surface water typology, physical surface water characteristics, significant anthropogenic pressures, water status and the limits of protected zones which are directly or indirectly linked to the water resource*. The delimitation and identification process of water bodies entails the classification of water bodies in three categories: *natural or quasi-natural, heavily modified, artificial.* Water bodies which have been preliminary defined as being heavily modified have undergone the test for the heavily modified water bodies' designation.

For the Danube River (sector Baziaș – Isaccea), **4 bodies of surface water** have been delineated, out of which 2 water bodies - rivers (Ostrovul Mare – Chiciu and Chiciu – Isaccea) and 2 water bodies - reservoirs (Iron Gates and Ostrovul Mare).

Along the Romanian section of the Danube River, **4 heavily modified water bodies** have been identified:

1. **Water Body 1 – Iron Gates (Baziaș – Iron Gates)** – km 1075-943 (132 km)
2. **Water Body 2** – **Ostrovul Mare (Iron Gates – Ostrovul Mare) –** km 943-863 (80 km)
3. **Water Body 3 - Ostrovul Mare - Chiciu / Silistra** - km 863-375,5 (487,5 km)
4. **Water Body 4 - Chiciu / Silistra - Isaccea** - km 375,5-100 (275,5 km).

7.3. Assessment of anthropogenic pressures and their impact

In the Water Framework Directive it is specified that the Member States shall analyze the type and magnitude of significant anthropogenic pressures to which bodies of water are subjected, taking the following into consideration: *point pollution sources, diffuse pollution sources, water abstractions, the regulation and damming of rivers, morphological alterations, other types of pressures with significant anthropogenic impact and land use.*

The steps towards the identification of anthropogenic pressures and the assessment of the impact of human activities on water are described in figure 7.1. For Romania, a national methodology has been developed: *Methodological elements regarding the identification of point and diffuse pollution sources and the assessment of their impact on surface waters.*

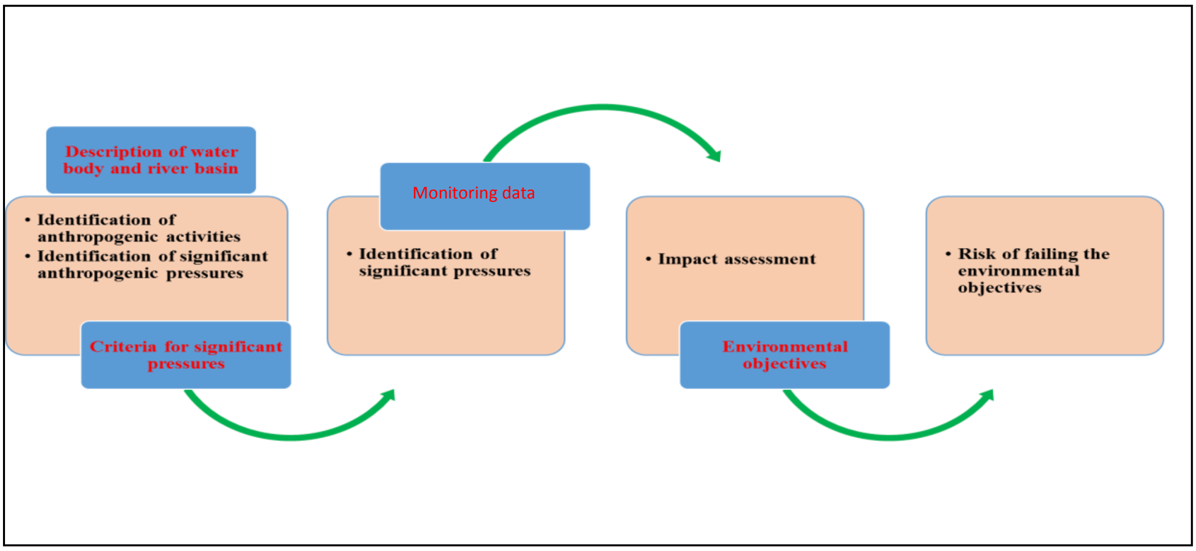

Figure 7.1. Steps of the assessment of anthropogenic pressures and impact on water

The identification and assessment of anthropogenic pressures for the four bodies of water delineated along the lower sector of the Danube River (between Baziaș and Isaccea) has led to the following results:

- ***Point pollution sources***

In the study, the identification and assessment of pressures was developed using data for 2015. Thus, ***human agglomerations*** which discharge urban wastewaters in the 4 bodies along the Danube sector were considered – ***19 human agglomerations***, out of which 17 agglomerations with over 2000 p.e. (population equivalent) and 2 agglomerations under 2000 p.e. with centralized sewers. (figure 7.2).

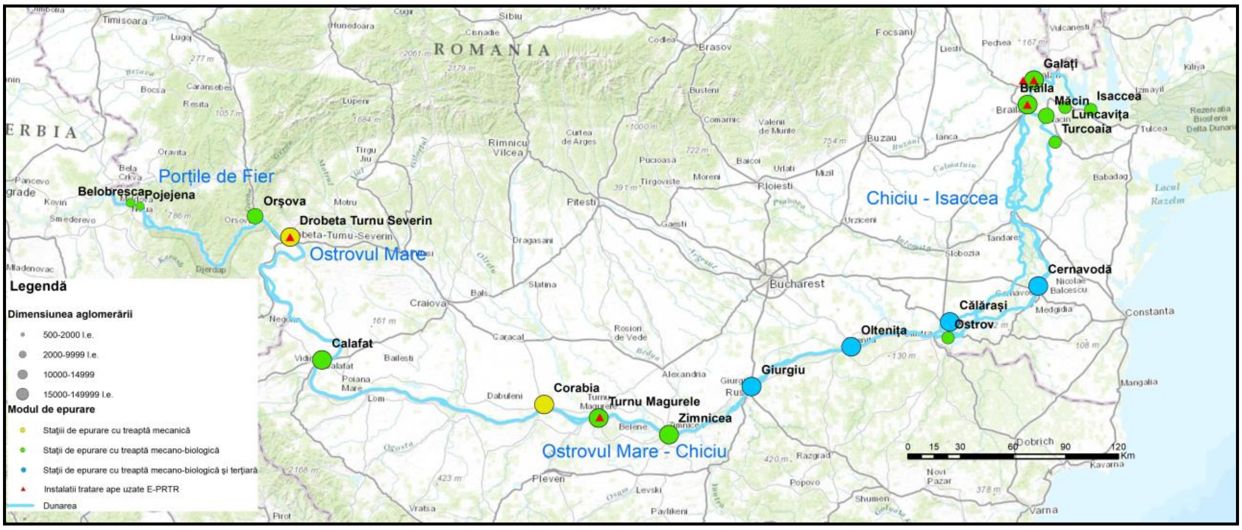

Figure 7.2. Point pollution sources (urban and industrial) on the Danube River lower sector

Quantities of suspended solids, organic substances, nutrients, heavy metals and other specific pollutants discharged from human agglomerations were quantified for every water body. In addition, urban and industrial pollution sources were identified and analysed from the perspective of their pollutant contributions, in conformity with the European Pollutant Release and Transfer Register (E-PRTR).

- ***Diffuse pollution sources***

Through the application of the MONERIS Model at the level of analytical units (sub-basins of the lower Danube River), using data for the period 2009 - 2012, the diffuse pollution pathways were identified and quantified, such as atmospheric deposition, tile drainage flow, soil erosion, groundwater flow and urban systems flow (figure 7.3 and 7.4).

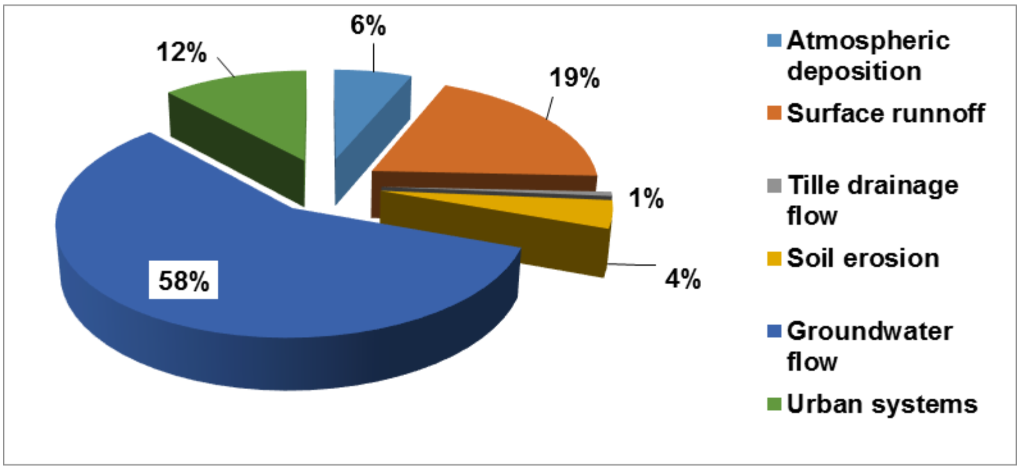

Figure 7.3. Pathways of nitrogen diffuse pollution on the Danube River lower sector

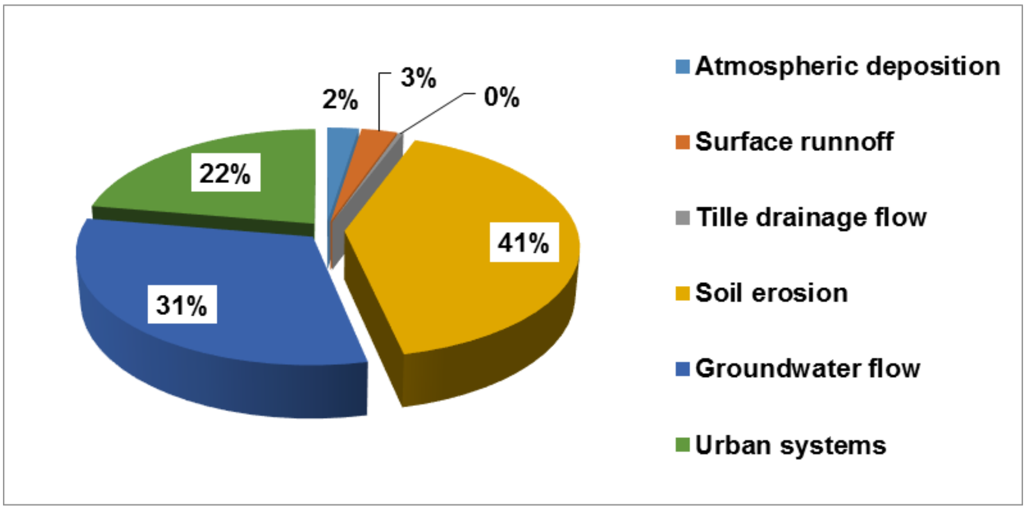

Figure 7.4. Pathways of phosphorous diffuse pollution on the Danube River lower sector

It can be observed that the biggest contribution of nitrogen is groundwater flow, runoff and urban areas, while for phosphorus, the main pathways of diffuse pollution are soil erosion, groundwater flow and urban systems. By selecting the analytical units (sub-basins) in the Danube catchment basin whose diffuse emissions reach the Danube River, the quantities of nutrients coming from agriculture, human agglomerations, other activities (industrial and transport), as well as from natural background.

From the perspective of specific emissions (emissions of nitrogen and phosphorus per area, from all point and diffuse pollution sources – kg/ha), analysed through the MONERIS model, average specific emissions of 6.05 kg/ha for nitrogen and 0.29 kg/ha for phosphorus have been resulted for analytical units on the lower Danube River. In the figures 7.5 and 7.6, the total specific emissions for phosphorus and nitrogen are presented on the level of 14 analytical units. It can be observed that the highest amounts of specific emissions can be found in analytical units corresponding to water bodies 3 and 4 (downstream of the confluence of the Olt River).

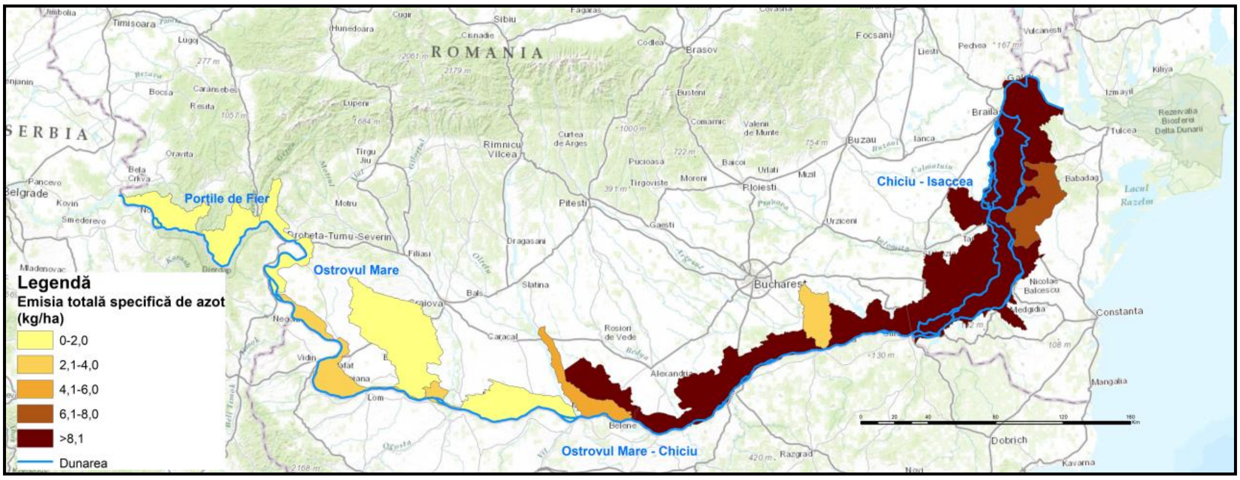

Figure 7.5. Nitrogen total specific emmissions (point and diffuse sources)

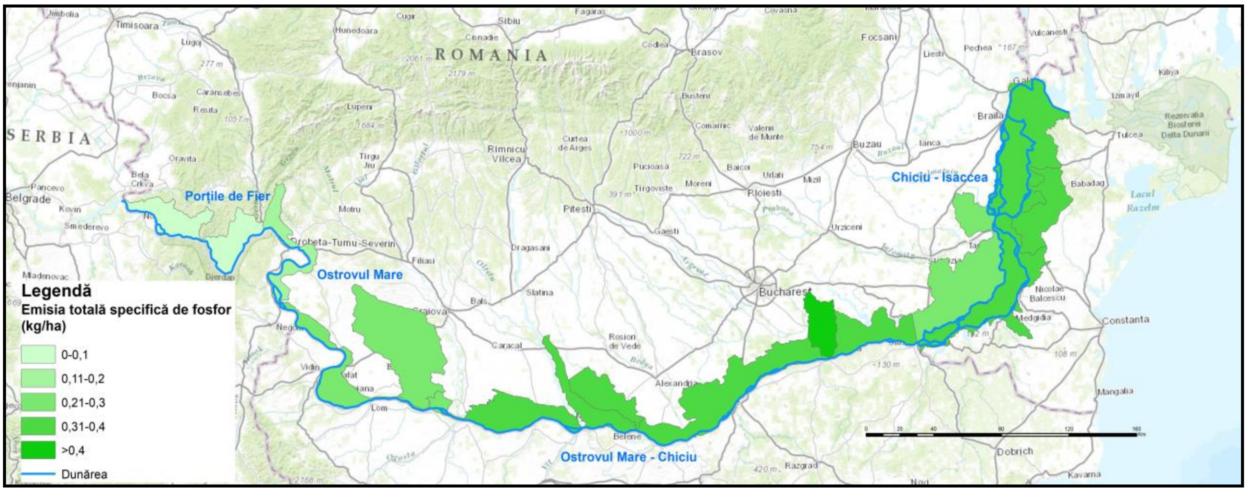

Figure 7.6. Phosphorous total specific emmissions (point and diffuse sources)

- ***Hydromorphological pressures***

Out of the existing hydraulic works on the lower sector of the Danube River (figure 7.7), the most important are: riverbed regulation, the damming of the Danube floodplains hydropower and navigation systems Iron Gates and Ostrovul Mare, irrigation systems, shipyards, as well as the Danube – Black Sea canal.

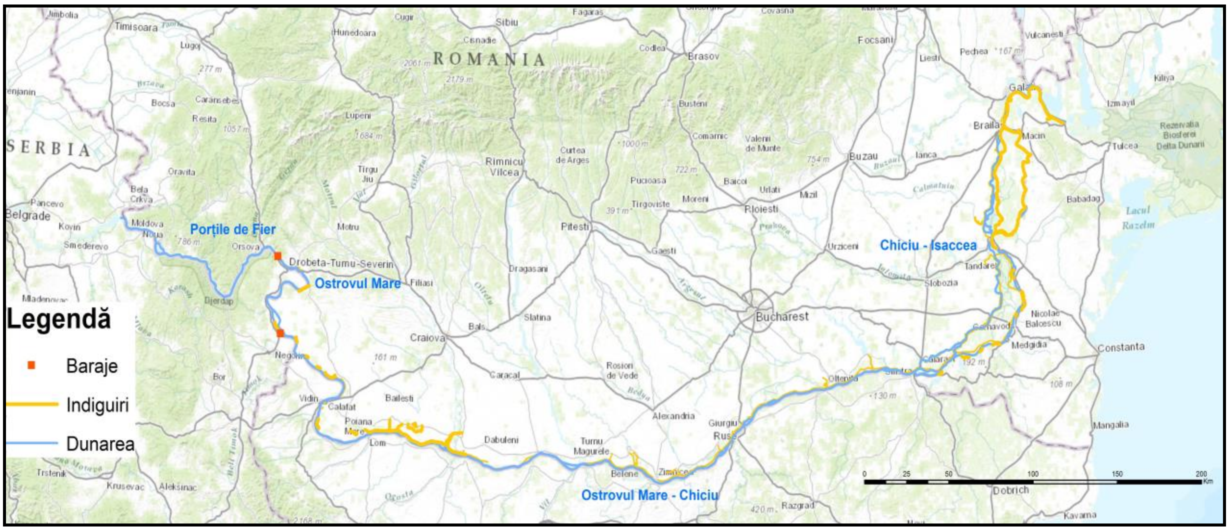

Figure 7.7. Main hydraulic works on the Danube River lower sector

The designation of heavily modified water bodies was done in accordance to the provisions of the Water Framework Directive, the European guidance and national methodology. **The designation of heavily modified water bodies on the Danube River** is the result of a long series of profound discussions and analyses, in which numerous universities, institutions and organizations have taken part.

The assessment of failing good ecological status was considered to be the first step (prior condition) in the process regarding the final classification of heavily modified water bodies on the Danube River.

The application of the evaluation system on the Danube river, on the basis of enhancing the conceptual and analytical framework and considering the lower Danube as a complex system (floodplain - water bodies) defined through complex and strong interactions and interdependencies between the riverbed and the lentic, lotic and terrestrial systems – aquatic ecosystems in the floodplain, has led to the conclusion that the water bodies are not in a good ecological status.

The designation of water bodies on the lower Danube River as heavily modified water bodies has been done taking the ***hydromorphological alterations*** into account, which are determined by physical alterations, large scale substantial changes of natural characteristics, profound and permanent modifications.

7.4. Interdependence of the water bodies on the lower sector of the Danube River with groundwater bodies

The application of geological, hydrodynamic and chemical and qualitative status criteria has led to the identification and delineation of groundwater bodies. The interdependence of groundwater bodies with bodies of water on the lower Danube River is presented in figure 7.8. It may be remarked that out of the 11 groundwater bodies which are interdependent to the surface water, 8 are in good chemical status and 3 are in bad chemical status, due to nitrate pollution.

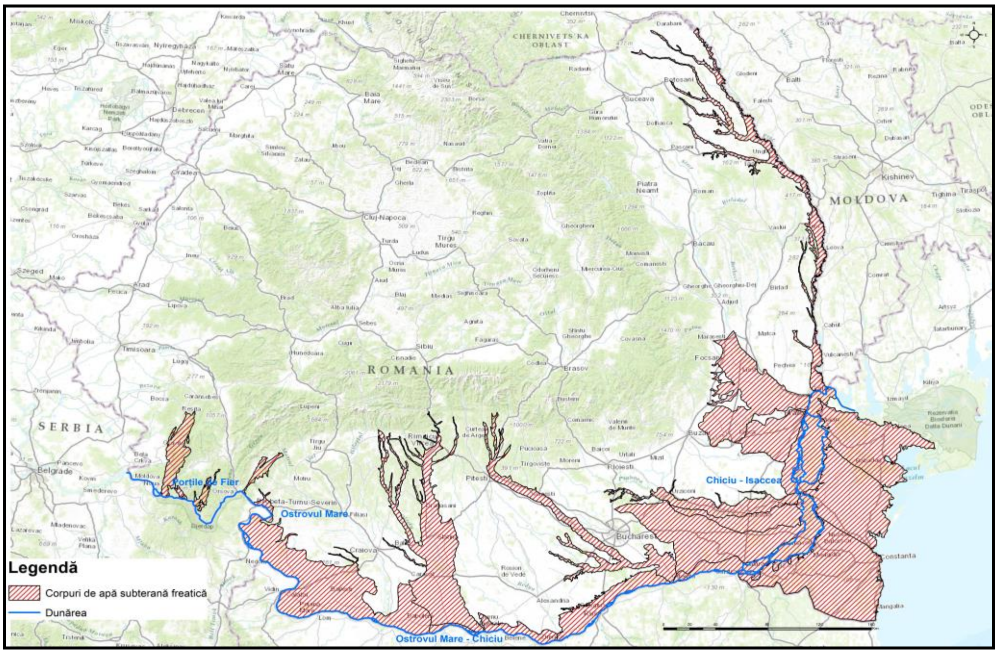

Figure 7.8. Groundwater bodies in interdepence with surface water bodies on the Danube River lower sector

7.5. Protected zones

These zones have been identified and have their own objectives, standards and implementation measures in conformity with relevant European legislation.

Protection zones for drinking water intakes

Water abstractions which are used for drinking water purposes are protected through the setting protection zones meant to avoid quality deterioration and the reduction of treatment levels in the process of producing drinking water. In accordance to current legislation, sanitary protection zones are established, with different levels of risk towards pollution factors: severe regime sanitary protection zones, restricted regime sanitary protection zones, hydrogeological protection perimeter, defined by HG no. 930/2005 *regarding the character and size of sanitary protection zones.* In the lower sector of the Danube River, 10 water abstractions have been identified together with their respective protection zones.

Zones for the protection of economically important aquatic species

In Romania, the definition of the sectors for the protection of economically important aquatic species was done through the identification of rivers with fish which have economic importance. Sectors where commercial fishing is undertaken were identified using information on significant catches for fish species. In conformity with the reports done by the National Agency for Fishing and Aquaculture, commercial fishing is practiced along the entire lower sector of the Danube River.

Protected zones for the habitats and species where water is an important factor

For the identification of habitats and species protected areas where water is an important factor, the natural protected areas which are linked to water bodies and which shelter species and natural habitats which are potentially dependent on the aquatic environment have been taken into consideration. The national legislation stipulates that, in order to ensure special protection and conservation measures for the natural patrimony, a differentiated protection and management regime must be instituted, delimitating several categories of protected natural areas.

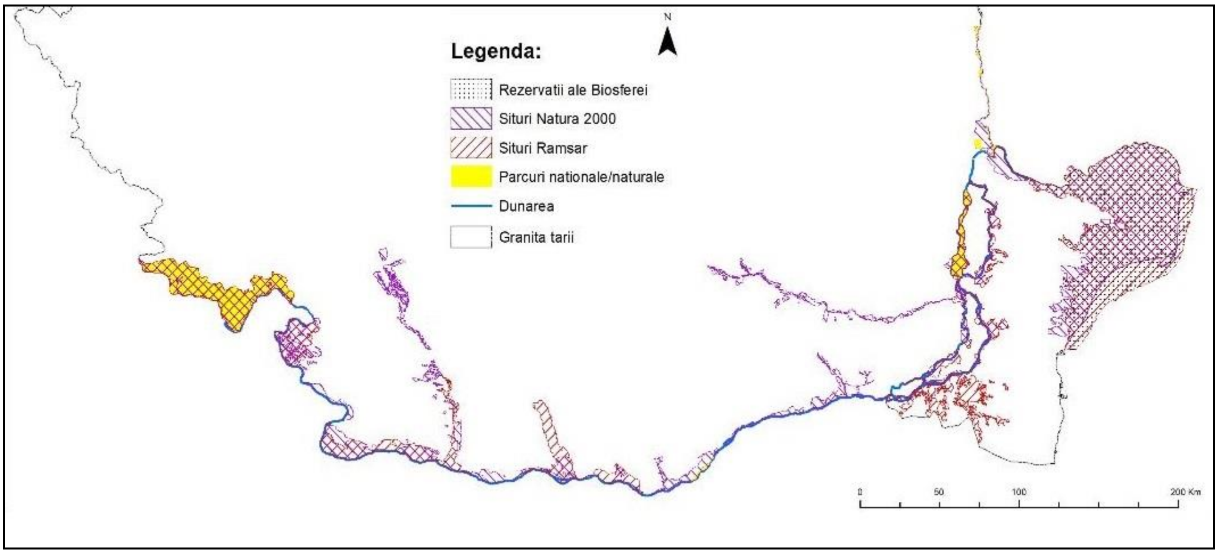

Figure 7.9. Natural protected areas in the lower Danube River Basin

On the lower sector of the Danube River, the identified natural protected areas are: 5 nature reserve under the protection of the International Union for Nature Conservation, 13 RAMSAR sites, 15 sites of importance to the community (SCI – Natura 2000); 22 areas of special avifauna protection (SPA – Natura 2000) as well as the Danube Delta Biosphere Reserve (figure 7.9).

Nutrients sensitive zones and nitrates vulnerable zones

Taking the need to prevent eutrophication phenomena into consideration, the national authorities have declared the entire territory of Romania as an nutrients sensitive area, this leads to the obligation for human agglomerations over 10,000 PE to ensure advanced wastewater treatment and the removal of nutrients (according to the requirements of *GD 188/2001 for approval of some norms on conditions of discharges of wastewater in aquatic environment, with subsequent amendments).* In accordance with the requirements of the national law *(GD* 964/2000 *on the approval of the Action Plan for the protection of waters against nitrate pollutions from agricultural sources*), Romania is no longer obliged to delineate nitrates vulnerable zones, due to the fact that the action plan is applied throughout the entire territory of the country.

8. ASSESSMENT OF THE STATUS OF THE WATER BODIES ON THE DANUBE RIVER BETWEEN BAZIAȘ AND ISACCEA

8.1. Water bodies monitoring

A process of modernization for the water monitoring system has taken place in the period between 2005 and 2006 in Romania. The National Integrated Water Monitoring System was developed to be in line with the requirements of the Water Framework Directive as well as other European directives in the water field. The main guidelines and requirements for the monitoring of new components and new parameters are based on consideration of the effect-pressure relationship (pressure-impact), according to which the biological components are the main elements in the evaluation of the ecological status of the waters, the physico-chemical and hydromorphological elements being support for the biological ones.

The monitoring network at the level of the 4 water bodies of the Danube River (sector Baziaș – Isaccea) is made up of gauging stations and quality monitoring sites (sometimes they are common). The monitoring network for hydromorphological elements is made up of 38 gauging stations. The biological elements, physico-chemical elements and priority substances are monitored in the monitoring sites of TNMN, respective in the 6 sites (3 profiles: left, right and middle) (chapter 3). To the quality sites monitoring and gauging stations presented earlier, the monitoring sites for water abstractions for the purpose of drinking water are added (sub-chapter 7.5), where physico-chemical elements, priority substances (depending on substances evacuated in the aquatic environment) and bacteriological parameters are monitored, in conformity with the present legislation.

8.2. Methodology for assessment of ecological status/potential and chemical status of the surface water bodies

In conformity with the Water Framework Directive, *the status of surface water* is the general expression of the status of a body of water, assessed in accordance to the most unfavourable value of its ecological and chemical status. Thus, the *good status* of a surface water body is achieved when both its ecological and chemical status are at least good.

The ecological status is the expression of the quality of structure and functionality of the aquatic ecosystems associated with surface waters; it is defined through *biological qualitative elements*, as well as *hydromorphological and general physico-chemical elements and specific pollutants (synthetic and non-synthetic)*, as a support function for the biological components. According to the Water Framework Directive, the 5 *classes of ecological status* are: *high, good, moderate, poor* and *bad*. The biological elements are taken into consideration for defining all 5 classes, while physico-chemical elements are taken into consideration in the characterization of high and good status, and hydromorphological elements are only taken into consideration for high status. In case of heavily modified and artificial water bodies, *the ecological potential classes* are defined as follows: *maximum and good, moderate, poor and bad.*

Good chemical status of surface waters is the chemical status achieved by a water body when pollutant concentrations do not exceed the environmental quality standards. Environmental quality standards are defined as the pollutant and groups of pollutant concentrations in water, sediments and biota which should not be exceeded for ensuring protection for human health and environment. Environmental quality standards for priority substances are defined by the *Directive 2008/105/EC amended by the Directive 2013/39/EU as regards priority substances in the field of water policy.*

The classification of chemical status is made in two classes (good chemical status and failing to achieve good /bad chemical status). At the same time, in order to be in line with the principle of non-deterioration, analyses are conducted to see whether priority substances have a trend to accumulate in sediments and/or biota, which could led on long term to the deterioration of good status. In this context, their trend is monitored and analysed, in the sense that the concentration values for these substances in sediments and/or biota do not present a temporal increasing trend.

In the assessment and classification process for the water bodies status, "*one out – all out*" principle (*the most unfavourable situation dictates*) is applied, as it is stated in European guidance documents developed for the implementation process of the Water Framework Directive.

8.3. Assessment of ecological potential and chemical status of water bodies located on the Danube River lower sector

As it has been specified in sub-chapter 7.3, the 4 bodies of water on the Baziaș – Isaccea sector are identified as heavily modified bodies of water and have been classified through ecological potential and chemical status. For their classification, the monitoring data for previously mentioned elements were compared with limits stipulated by the Classification and assessment system for surface water bodies (the annex of the National Management Plan). In the following, the results of the evaluation of the 4 studied bodies of water in the two Management Plans are presented:

- **Ecologic potential**

- For biological elements:
  - In the second Management Plan, 4 biological qualitative elements were evaluated, in comparison with one element (benthic invertebrates) evaluated in the first Management Plan; thus, in the evaluation of potential, phytoplankton, phytobentos and fish fauna were added;
  - In both situations, the potential remained moderate (even the benthic invertebrates potential improved in all 4 water bodies), due to the application of the "one out – all out" principle;
- For hydromorphological elements:

- In the second Management Plan, all hydromorphological elements were evaluated, in conformity with an improved methodology elaborated by INHGA, based on monitoring data registered on the lower sector of the Danube River;
- The potential was found to be moderate in all 4 bodies of water due to the longitudinal (due to the two dams) and lateral (because of extensive damming) continuity and morphological conditions;

- For physico-chemical elements:
  - In the second Management Plan, more qualitative parameters (to which general parameters were added: salinity (conductivity), oxygenation conditions (BOD_5 and CCO-Cr), nutrients regime (total nitrogen) and specific pollutants (cyanides and anion-active detergents);
  - If in the first Management Plan only the Ostrovul Mare water body had a moderate potential (the rest 3 bodies of water were evaluated in good potential), in the second Management Plan the first 3 bodies of water were evaluated at moderate potential due to the anion-active detergents and in the case of Ostrovul Mare water body, due to the chemical oxygen demand(COD-Cr);
  - Even the water quality has improved in the last years (chapter 3), the potential has decreased for the Iron Gates and Ostrovul Mare-Chiciu bodies of water due to the evaluation of more parameters and the application of "one out – all out" principle;

- **Chemical status**

- chemical status of Chiciu – Isaccea body of water has imporved, now achieving good status;
- chemical status of the 3 bodies of water (located between Baziaș and Chiciu) has improved even they have not yet achieved good status; despite their present status, the number of substances and groups of substances which exceed environmental quality standards has decreased (only a single substance);
- confidence in the evaluation has increased, through the increase of monitored substances number and investigation environments (water, sediment, biota).

8.4. Proposal of improvement of the application manner of the methodology for the assessment of water bodies status from the physico-chemical elements perspective

Corroborating all results in this study with the practical experience of developing and coordinating the 2 National Management Plans, especially regarding aspects for the status assessment, anthropogenic pressures and their impact analysis, as well as the setting measures for the achievement of environmental objectives foreseen by the Water Framework Directive, I consider that *the application manner of the assessment methodology of the ecological potential/status of water bodies (from the perspective of physico-chemical) can be improved.*

As it has been specified in previous sub-chapters, the evaluation of water body status for the purpose of developing and updating river basin management plans was conducted mainly on the basis of data gathered during one year. In the situation when monitoring data for the year 2013 were not available, data from another year were used (2011 or 2012 for the updated National Management Plan). There have been situations when for a physico-chemical indicator, the evaluation showed another potential/status class for each year, and the types and magnitude of pressures were observed, showing a partly natural variation/dependency on other primary parameters (as shown in chapters 2, 3, 4, and 5). In this context it was difficult to establish the real status, in the absence of a procedure for data evaluation and analysis.

The sole condition in regards to application is that the pressure types and magnitude, as well as the dynamic of measures implementation should be quasi-constant. Thus, in contrary situations the evaluation during a period of 2-3 years is advised.

Further, I have analysed the methodology application manner (proposal for improving application method) for the assessment of water body status/potential for a monitoring site, considering general physico-chemical elements (oxygenation conditions and nutrient regime parameters).

Improved application stages for the assessment methodology of water body status/potential for general physico-chemical elements are:

- obtaining primary monitoring data for the respective indicator;
- calculation of the annual C90 percentile through the aggregation of data sets for one or all monitoring sites located on the water body;
- calculation of the arithmetic mean of annual percentiles (annual C90) for a period of 3 years and 6 years, respectively (M90);

- comparison of M90 and M10 (for dissolved oxygen) previously calculated with the limits between *high* and *good (H/G)*, respective *good* and *moderate (G/M)* specifically to water body typology and then classification in *high*, *good* or *moderate* status.

  The status given by general physico-chemical elements is obtained through the application of *one out all out* principle.

  The advantages in applying this assessment method are:
- availability of a longer series of data for the statistic processing of the 90 or 10 percentile;
- availability of a larger number of monitoring sites, taking into consideration the investigative monitoring (through the movement of monitoring sites from monitored water bodies which have reached environmental objectives to unmonitored bodies of water evaluated through grouping approach with other bodies of water or on the basis of risk analysis);
- possibility of evaluating multiple bodies of water, considering the availability of a larger number of sites (through the aspects mentioned on the previous point);
- avoiding situations in which water bodies are differently classified every year due to natural parameters variations depending on climatic aspects (years with drought, years with floods, periods of extreme climate);
- higher confidence in the water bodies status/potential assessment process.

The application of potential evaluation methodology for general physico-chemical parameters (oxygenation conditions and nutrient regime parameters) was developed using data from Reni monitoring site (Chiciu-Isaccea water body) for the period 2010 - 2015 (6 years) and for the period 2013 - 2015 (3 years). The results of the comparative application of the initial methodology with the annual assessment using the 90 percentile/C90, with the improved methodology with the assessment for a period using mean of yearly C90 /M90 for oxygenation conditions parameters are presented in table 8.1.

Table 8.1. Application of ecological potential assessment methodology for oxygenation conditions parameters in Reni monitoring site (Chiciu – Isaccea water body)

Assessment year	COD-Cr		BOD_5		Dissolved oxygen		Oxygenation conditions potential
	C90	Potential class	C90	Potential class	C10	Potential class	
2010	27,94	M	2,43	H	7,0	G	M
2011	30,45	M	3,20	G	7,4	G	M
2012	21,94	G	4,44	G	7,1	G	G
2013	15,83	G	3,40	G	7,6	G	G
2014	19,72	G	2,37	H	7,5	G	G
2015	18,69	G	2,38	H	8,3	G	G
Assessment period	**M90**		**M90**		**M10**		
2013-2015	18,08	G	2,72	H	7,82	G	G
2010-2015	22,43	G	3,04	G	7,49	G	G

9. METHODS AND WORKING TEHNIQUES

The specific thematic area of the present study fits into European and national scientific and management concerns through the approached issues which allow an integrated assessment of quantitative and qualitative aspects, of natural characteristics with the impact of anthropogenic pressures, of the impact of climatic changes on qualitative characteristics, of the risk of failing good water status in order to establish measures which shall be implemented for reaching environmental objectives, in conformity with the Water Framework Directive provisions for the protection of aquatic ecosystems and the sustainable use of water resources.

The work methods used in the development of the thesis are grouped in study stages such as the preliminary stage, processing stage and final stage.

The **preliminary stage** consisted of the identification and selection of information sources, the collection of data, the analysis and assessment of geographical and water management studies. These studies regarded hydrological and water quality characteristics, water legislation and synthesis papers for studies, national and international projects from which only relevant and interest information for the analysed sector were extracted using data and information selection and grouping criteria.

The **processing stage** was carried out through the obtaining visual information (**the observation method**) on geographical characteristics, anthropogenic pressures as well as their impact, the knowledge on the territory to be analysed as well as the processing of data, information and knowledge gathered, as they are important in the analysis of information collected in the preliminary stage and in interpreting the results obtained.

For the analysis of the collected information, the **selection method** was used, applied when selecting the monitoring sites, gauging stations, time series, as well as the elements/parameters to be studied.

The **synthesis method** was used for the eloquent presentation of issues and results; this method allowed for grouping of information and drawing conclusions for an optimal comprehension of processes and information. Through the synthesis method, the cause-effect relationship was analysed, as well as the pressure-impact-risk-status on water bodies studied located on the Danube River, but also the effect of the joining with the polluted tributaries from Romania and Bulgaria, the multidisciplinary integration and correlation between quantity and quality, hydrological regime and physico-chemical characteristics, global change impact on physico-chemical parameters, as well as the application of the MONERIS model for the estimation of diffuse nutrient emissions in the studied area.

Maps were developed with the aid of the **mapping method** through the geographical information system (GIS), and their analysis allowed for the better understanding of relevant information and assessments for the studied area.

The **final stage** consisted of the synthesizing and interpretation of the results obtained during previous stages, the statistical data interpretation for hydrological, physico-chemical and biological elements/parameters, the correlation of raw and processed data and their integration, the text elaboration through analyses interpretation and results obtained, of thematic maps and charts, the development of proposals for the improved application of some national methodologies and the finalization of the thesis through drawing conclusions.

10. PERSONAL CONTRIBUTIONS

The thesis, through personal contributions, represents a progress and development in the field of geographical knowledge, integrated characterization and quantitative and qualitative assessment, temporal and spatial evaluation of the Danube River and its associated aquatic ecosystems. Through both thesis scientific and practical issues of water resources management and planning with practical applicability in present activities, are important at the national and river basin level, too.

The personal contributions can be structured in the following manner:

- physico-geographical analysis of the Danube River Basin and hydrological analysis of its entire course;
- processing and analysis of data (annual and multiannual average concentrations, minimum and maximum concentrations, 50 and 90 percentile) taking the spatial variation into consideration (from Germany to Romania) and the temporal variation (period 2006 – 2015, with an accent on 2015) of monitored physico-chemical and biological indicators in the main monitoring sites, as well as the interpreting of results, with the description of natural and anthropogenic sources, as well as their behaviour and toxicity within the aquatic environment;
- analysis of the hydrological regime on the lower sector of the Danube River in regards to discharge parameters (average, minimum and maximum flows on an annual, decadal and multiannual basis, the seasonal distribution of discharge), the variation and temporal and spatial trend at the main gauging stations, the characterization of both low and high water hypostases, as well as the influence of hydraulic works on discharge regime;
- processing and analysis of data (minimum, average and maximum annual, multiannual concentrations during a period of 20 years, from 1996 to 2015) and the evaluation of water quality on the lower sector of the Danube River (Baziaș – Isaccea) done at the level of representative monitoring sites and profiles where the variation and spatial and temporal trends of physico-chemical and biological quality elements (41 parameters) were evaluated, selected in order to reflect both general characteristics and the effect/impact of the main pressures identified at the river basin level: organic pollution, nutrients pollution and hazardous substances pollution; moreover, the interdependencies among these parameters have been analysed, along with their behaviour, the transformations/reactions occurring as a result of sedimentation/re-suspension processes, the correlation with tributary and pollution sources contributions; tendencies towards the improvement of water quality were correlated with implemented measures for the reduction of point and diffuse pollution resulted from human agglomerations and industrial and agricultural activities;

- analysis of the dependency of qualitative aspects (physico-chemical parameters) with quantitative aspects in 3 representative monitoring sites and the obtainment of correlations between flow (annual and daily average values) and loads of 17 determinants/pollutants (annual average values) transported by the Danube River, as well as their concentrations (annual averages and daily values) for a period of 10 years, with further details on years different from hydrological regime point of view;
- evaluation of the impact of climatic changes on water quality in the lower sector of the Danube River, the multiannual variation of concentration for oxygenation conditions and nutrient regime parameters (6 parameters) and their correlation with the variation of water temperature as well as the monthly multiannual variation of these parameters during two decades in the Reni monitoring site. On the basis of multiannual monthly trends of water temperature, their effect on the oxygenation and nutrient regime parameters was studied and interpreted, considering the oxygen, carbon, nitrogen and phosphorus cycles processes, as well as the oxidation of organic substances, the nitrification-denitrification process and the production of phytoplankton. The variation of oxygenation conditions and nutrient regime parameters concentrations with the 2003 and 2006 hydrological regime was analyzed;
- detailed characterization of the studied sector of the Danube River from the perspective of typology, delineation of water bodies, with the consideration, updating and evaluation of anthropogenic pressures, impact analysis and evaluation of risk of failing to achieve environmental objectives, as well as the interdependence with associated groundwater bodies and protected areas;
- justification/validation of water bodies (on the lower sector of the Danube River) designation as being heavily modified from the perspective of their profound and permanent altered character;
- quantification of diffuse nitrogen and phosphorus emissions in the hydrographic sub-basin of the studied sector through the application of the MONERIS model and the identification of diffuse emission sources and pathways;
- critical analysis of the application manner of the methodology for ecological status/potential and chemical status assessment and the comparative analysis of results obtained for the studied water bodies in the National Management Plan and its update;

- elaboration of proposal towards the improved of the application manner for the methodology for the ecological status/potential assessment of water bodies, regarding physico-chemical elements, taking all aspects discussed throughout the thesis into account, the description of advantages in the practical application, its testing on a body of water and the comparative analysis of results.

Through the elaboration of this study, an important contribution has been brought to the knowledge, characterization and evaluation of the lower sector of the Danube River, the obtained results can be used in the water sustainable management, as well as in activities for updating the River Basin Management Plans, improvement of monitoring programs efficiency, assessment of water status and setting the programs of measures for reduction of anthropogenic pressures and mitigation of their effects for reaching and maintaining environmental objectives.

CONCLUSIONS

Study on the status of the water bodies from the lower sector of the Danube River between Baziaş and Isaccea has had as a main objective the spatial and temporal characterization and the evaluation of the status of the 4 water bodies on the lower sector of the Danube River, for a better implementation, from scientific and practical point of view, of provisions of the European Directives in the water quality field and international conventions regarding the protection and sustainable use of water resources and aquatic ecosystems of the Danube River.

In the context of European and national policies regarding the integrated management of water for achieving and maintaining environmental objectives at the water body level, this thesis presents modern concepts and principles introduced by the Water Framework Directive. On this basis and using afferent monitoring data, information and studies, the thesis has developed a detailed characterization from the perspective of the integration of natural characteristics with anthropogenic pressures, the analysis of their effect from hydrological and physico-chemical point of view, as well as the assessment of the 4 water bodies from the lower sector of the Danube River.

The thematic of the thesis is particularly useful, having in view the obligations of competent authorities to implement the European legislation, which based on knowledge, characterization and evaluation of water bodies, measures are set and implemented for the reduction of anthropogenic pressures impact and the achieving and maintaining environmental objectives.

The thesis, through the succession of detailed aspects, elaborated analyses and drawn conclusions, has achieved its planned goals.

Study on the status of the water bodies from the lower sector of the Danube River between Baziaş and Isaccea has a significant contribution to the study of the lower sector of the Danube River, characterizing the 975 km of its studied sector in an original and interdisciplinary manner, from qualitative and quantitative perspective, taking the magnitude and spatial dynamics into consideration, as well as the temporal dynamic for hydromorphological, physico-chemical and biological parameters, considering natural aspects as well as the effect of anthropogenic pressures and the implemented measures, as well as the impact of climatic changes.

The results obtained from the spatial and temporal analysis of hydrological and physico-chemical parameters constitutes an useful instrument in the analysis, revision and streamlining of the Integrated Water Monitoring System from the perspective of network, monitoring programs, as well as of monitored parameters and frequency they are analysed. The integration and corroboration of quantitative aspects with qualitative ones, as it was done in this study, is an instrument which contributes to the estimation of effects of the two hydrological phases (low waters and high waters) on water quality (from physico-chemical perspective).

The comprehensive characterization and analysis of anthropogenic pressures and their correlation with the water quality and status is especially useful from the perspective of establishing cost efficient measures which lead to achievement of and maintaining environmental objectives. Moreover, the detailed characterization of hydromorphological alterations and comparison with the natural situation (prior to their construction) of the lower sector of the Danube River is very useful in the justification of the designation of the 4 water bodies as heavily modified water bodies.

The quantification of the impact of climate change on water quality, as well as the quantification of the effects of measures taken to reduce anthropogenic impact on the short and medium term are useful means by which exceptions of reaching environmental objectives can be set, through the estimation of feasible timeframes, as well as from the perspective of justifying setting less stringent environmental objectives, as it is the case.

Taking into consideration the requirements of the European and national legislation, of the precise (with a high level of confidence) assessment of water status during a planning cycle, based on the advantages described, the proposed procedure for the assessment of ecological status and potential can be used in the next updating period of the River Basin Management Plans (2020-2021).

The results of the study will be transferred to the Romanian Waters National Administration and shall contribute to the technical and scientific foundation of management decisions taken in the Danube River Basin for the integrated management of water resources.

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