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STATUS, PROBLEMS AND SOLUTIONS CONCERNING SURFACE WATER MANAGEMENT IN BULGARIA

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Abstract

Water resource conservation and management is vital as well for humankind, as for nature and economy, and is exposed to anthropogenic and climatic pressures, transcends national boundaries. The EU Water Framework Directive 2000/60/EC establishes a legal framework to protect and restore clean water in the EU and to secure its long-term sustainable use and mitigate the effects of floods and drought. In this regard, EU member-states are developing river basin management plans based on current characteristics and water status and programs with measures. In the planning process were identified different types of pressures on the surface waters, defining the significant management issues, such as pollution with biogenic substances, organic and chemical pollution, pressure from water intake and climate pressure. These problems solutions require both science-based approaches and specific target measures definitions to improve the water resources status and the level of their management.

Key words*: chemical pollution, ecological status, scientific approaches, water intake.*

INTRODUCTION

To protect the water resources from the diverse anthropogenic impact in the conditions of global climate change is one of the main tasks for society to solve today at global, national and a local level. The main document implemented in the European Union countries is the European Framework Directive (Water Framework Directive, WFD) adopted in 2000 and regulating the integrated water management policies.

Among the WFD most important goals and tasks are the achievement by 2027 of good ecological and chemical status of all surface and underground waters through the river basin management plans (RBMPs), including analysis and assessment of the water current state, assessment of the pressure on water quality, and six years program of measures to limit the anthropogenic impact on water.

Given the territorial and climatic specifics, the internal flow of Bulgaria is relatively limited, but with the external inflow from the Danube River it increases several times.

Thus, the total fresh water resources, both in absolute volume and per capita, significantly exceed those, in a number of European countries.

The pressures of diverse nature on surface water identified in the planning process determine significant management problems in terms of quantitative and qualitative specifics among which in 2021 are identified: surface waters pollution with biogenic substances; organic and chemical pollution; pressure from water intake and physical modifications; and climate pressure. Solving these problems requires science-based approaches to improve the level of planning, including the selection of adequate measures for the current state of waters. These actions aim to achieve environmental goals and will generally improve water management.

This paper presents the evaluated based on the available methodologies state of the surface waters in the process of planning, highlighting the gaps and the important management issues. The upgrading of the methodological basis and the resolution of the problems require science-based approaches and mitigating measures.

MATERIALS AND METHODS

Territorial scope and main specifics of the area studied

Bulgaria has an area of 110912 km^2 located in the east Balkan Peninsula. It borders Romania in

the north, Serbia and North Macedonia in the west, Greece and Turkey in the south, and the Black Sea in the east. The National Statistical Institute (NSI) published data for 2021 indicate that the Bulgarian population is about 6.8 million people, with 73% living in urban areas. According to data by the Institute for market economy for 2019, the gross domestic product amounts is 67% for services, 28% for industry, and only 5% of agriculture.

The implementation of water management according to the basin principle pursuant the Water Resources Act and the provisions of Art. 3 of WFD Bulgaria is divided into four basin management regions (BMRs), distinguished by the natural location of the watersheds between the catchment areas of one or several main rivers (Table 1), namely:

- Danube River Basin District (DRBD),
- Black Sea River Basin District (BSRBD), - East Aegean River Basin District (EARBD),
- West Aegean River Basin District (WERBD).

In Figure 1 is represented the territorial scope of the basin regions, and on Figure 2 - their respective share of the area of Bulgaria.

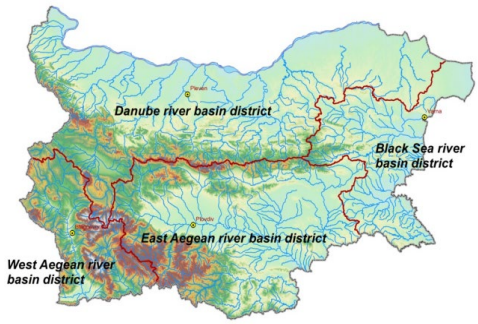

Figure 1. River Basin Districts in Bulgaria

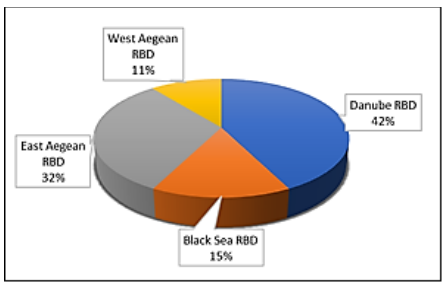

Figure 2. Share of the respective region from the total area of Bulgaria

Table 1. River Basin Districts (RBD) - main characteristics

RBD	Main river basins	Ecoregion
Danube River Basin District	Erma and Nishava, River west to Ogosta, Ogosta, Vit, Osam, Iskar, Yantra, Rusenski Lom, Danube and Dobrudjanski rivers	12 - Pontic province
Black Sea River Basin District	Black Sea Dobrudjanski rivers, Kamchia, Provadiiska, North Burgas rivers, Manderski rivers, South Burgas rivers, Veleka and Resovska rivers, Preseltsi-Chernomoretz gullets	7 and 12 - Eastern Balkan and Pontic province
East Aegean River Basin District	Maritsa, Tundja, Arda and Byala reka	7 - Eastern Balkan
West Aegean River Basin District	Struma, Mesta and Dospat	7 - Eastern Balkan

The Bulgarian climate most specific feature is the transition between the temperate and the Mediterranean (subtropical) climate with a slow but positive trend of growth in air temperature over the last century, unevenly distributed precipitation throughout the year, and frequent extreme events such as droughts and floods.

The year 2020 is the second warmest year since 1930 with an average annual temperature for Bulgaria of 12.4°C or 1.9°C above the climate average for the period 1961-1990, while in 2021 the average annual temperature is 11.8°C or 1.3°C higher than the climate average for the same period. The country average annual precipitation in 2020 is 594 mm or 93% of the norm, and that in 2021 is 766 mm or 20% above the norm (NIMH, 2020). Multi annual fluctuations in precipitation amounts are used as a regional climate change indicator and assessment of such economic sectors impact, specifically on agriculture (Alexandrov & Shopova, 2020), as well as a factor in the formation of national water resources.

The available renewable water resources of Bulgaria, excluding the external inflow from the Danube, the multiannual average for the period 1981-2020 are estimated to 15.8 billion m^3 distributed within the four basin areas, according to Figure 3 (NSI, EEA, 2020).

The average multi annual river runoff varies widely, most often at 50% supply at between 18.0 and 20.8 billion m^3/year, and at 95% supply it is 8.0-9.5 billion m^3/year. The volume of registered surface runoff for Bulgaria in 2020 was 10.1 billion m^3 and compared to the average multi-annual data for 1961-1990, 1971-2000, and 1981-2010, data indicate decrease by 45.2, 37.7%, and 35.0% respectively, thus being the smallest for the last five years (EEA, 2020). The participation in surface runoff for 2020 share is

respectively for: Danube catchment basin - 38.2%, Eastern Aegean basin - 37.6%, West Aegean basin - 19.1% and Black Sea - 5%.

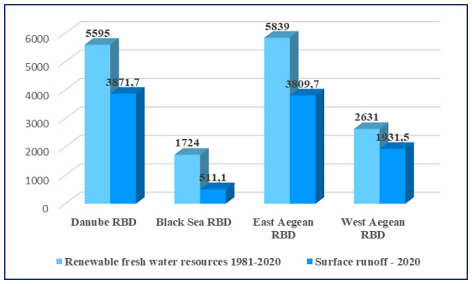

Figure 3. Available renewable fresh water resources without external inflow (1981-2020) and Surface runoff (2020) by the RBDs, mil. m^3

Within the current RBMPs 2016-2021, 955 surface water entities are defined (natural - 77%, highly modified - 21% and artificial - 2%), divided into four classes - rivers - 89%, lakes - 6.5%, with those specifics only for the RBRMs - transitional and coastal waters. Out of the identified types for Bulgaria under System B (Appendix No. 1 to Art. 2 of Ordinance H-4/14.09.2012 concerning the surface water characterization), considering multiple indicators - geomorphological, hydro morphological, biological, geological, hydraulic, the largest number water entities being of R3 - mountain type, followed by R4 - semi-mountainous rivers in the Pont province, and R5 - semi-mountainous type.

Assessment methods concerning surface waters pressure and condition, and the measures planning

Surface water management is based on an assessment of their ecological and chemical status adequate to the identified anthropogenic pressure, and the results of the monitoring and the potential risk of not achieving the goals, together with the harmful impact of the waters, determine the degree of significance.

The RBMPs conceptual model 'Drivers - Pressure - Status - Impact – Response' (DNSVO)' proposed in Guideline No. 3 'Analysis of Pressure and Impacts' of the General Strategy for the Implementation of the Water Framework Directive 2000/60/EC (WFD) has been applied as based on causal relationships and interaction between society, its economic activity, and the environment.

Driving forces (natural and anthropogenic) define the category and type of pressure which, as significant alone or in combination with other types of pressure, may negatively affect the ecological objectives of a water body (WB). The significant pressure is based on an assessment of monitoring data and how much they account for a change in condition from a certain impact with a potential risk of not achieving good condition. The ecological status/potential assessment of surface water entities for (natural, WWTP and artificial) in accordance with the requirements in Annex V of the WFD and Guideline No. 6, is carried out according to the following quality elements: biological (BEC), physical and chemical (FHEC - general indicators and specific pollutants) and hydro morphology as accepted scales specified in Table 2.

Table 2. Classification and designations of ecological status

Ecological status				
High	Good	Moderate	Poor	Bad
1	2	3	4	5

The BEC leading assessment is based on selected indices/metrics for the following elements - phytoplankton (lakes/dams), phytobenthos (rivers), macrophytes, macrozoobenthos (rivers) and fish fauna (rivers), and that of the main physical and chemical indicators (10 per number) - dissolved oxygen (DO), biochemical oxygen demand (BOD_5), ammonium (NH_4^+- N), nitrite (NO_2^--N) and nitrate (NO_3^--N) nitrogen, total nitrogen, phosphates (PO_4^{3-}-P), total phosphorus, electrical conductivity and pH of their average annual concentrations. This is regulated in points A and B of Appendix No. 6 in the above-mentioned Ordinance No. H-4/14.09.2012. Due to lack of an approved analysis methodology the hydro morphological state analysis is expert and based on monitoring data.

The excellent condition is determined with unobserved or minor deviations from the natural conditions and in all other cases good condition is defined (Table 3), as for the water bodies with a significant impact on BEK, indicative of hydro morphological pressure, a test is conducted to determine highly modified water bodies.

Table 3. Groups of indicators to evaluate the quality elements

Ecological status		
Biological elements	Physico-chemical elements	Hydromorphological elements
High	High	High
Good	Good	Good
Moderate	Moderate	
Poor		
Bad		
U	Unknown	

The chemical state of assessment surface waters is carried out based on the concentrations of priority substances and some other pollutants established during monitoring in accordance with the list and standards in Directive 2008/105/EC on setting environmental quality standards (EQS), transposed into Ordinance from 2010 on environmental quality standards for priority and other pollutants of the Bulgarian legislation.

A good chemical status is defined with average annual value (AAV) for each monitored priority substance does not exceed the AAV-EQS, and a bad one when the average value is greater than the AAV-AQS, according to Appendix 2 of the Ordinance on EQS (Table 4). In 2016 National methodology for assessing the chemical state of surface waters was adopted, which will be applied during the implementation period of the second RBMP.

Table 4. Assessment of chemical status of surface water bodies

Chemical status	Good	
	Bad	
	U	unknown

To preserve or improve the surface waters condition is developed a Program of Measures (PoM) as part of the RBM. The minimalist approach adopted in the first RBMP in PoM development is built on in the second plan with national approach that considers the interactions of driving force - pressure - impact - condition - environmental objectives - measures. The approach aims to ensure the planning of measures focused at specific type and sources of pressure, thus identifying significant problems in water management according the specific conditions and state of individual water entities. Each measure is related to concerned water entity and its determined driving force: urbanization, agriculture, energy, flood protection, industry, climate change, etc.

The measures (main, complementary, and additional) in the second program are drawn from a national catalog and may apply to more than one water entity or to an entire basin area. The main measures focus on compliance with the WFD minimum mandatory requirements and the Water Resources Act, while the complementary ones are enforced in cases where the main one's implementation is not sufficient for the good status.

If the main and the complementary measures do not produce the required result in the stipulated period, new "additional" measures are envisaged within the current RBMP with respect to the established anthropogenic pressure on a given water body. These measures are foreseen within the implementation of the RBMP should monitoring or other data indicate that the environmental protection objectives for a specific water entity cannot be achieved through planned measures and/or within the period set.

RESULTS AND DISCUSSIONS

Water conditions

Based on the assessment of the surface water state by the applied in the RBMP methods, the results from the monitoring in 2020 and the analysis of the National Report on the State and Protection of the Environment in Bulgaria for 2020, the following generalizations can be made:

- In 2020 the number of water entities in excellent and moderate conditions increased by 39.6% and 26.6%, respectively, and those in good conditions decreased by 90.6% compared to the second planning period 2016-2021, while keeping the positive trend for the main physical and chemical indicators (Table 5, Figure 4).
- The monitoring results for 2020 regarding the biological quality elements indicate that in 74% of surface water points in category *rivers* and 63% in category *lakes* the objectives for good conditions are not fulfilled, while the assessment of main physical and chemical indicators shows that most examined points are in excellent and good conditions. During 1996-2020 is registered a decrease in the concentrations of O_2, NH_4-N, N-NO_3, BOD_5 and PO_4^{3-}-P (EEA, 2020);

- The chemical state improvements for surface water entities are insignificant, with 64% being not assessed due to missing monitoring data and laboratory analysis methods for some priority substances (Table 6).

Table 5. Ecological status of the surface water bodies by the RBDs - RBMP 2016-2021 - Annual report 2020

Ecological status/potential / River Basin District	Danube		Black Sea	
	RBMP 2016-2021	Annual report 2020	RBMP 2016-2021	Annual report 2020
1 (high)	19	27	5	10
2 (good)	94	83	72	32
3 (moderate)	59	79	83	97
4 (poor)	22	14	25	10
5 (bad)	11	8	20	6
U (unknow)	51	1	0	33
no monitoring	0	44	0	17
Total	**256**	**256**	**205**	**205**
Ecological status/potential / River Basin District	**East Aegean**		**West Aegean**	
	RBMP 2016-2021	Annual report 2020	RBMP 2016-2021	Annual report 2020
1 (high)	18	4	11	33
2 (good)	105	112	103	69
3 (moderate)	112	143	51	67
4 (poor)	26	37	8	9
5 (bad)	12	14	5	2
U (unknow)	38	1	5	0
no monitoring	0	0	0	3
Total	**311**	**311**	**183**	**183**

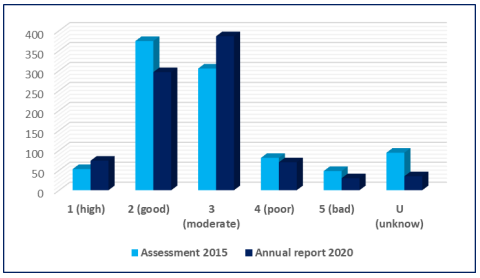

Figure 4. Total ecological status of the surface water bodies in Bulgaria

Table 6. Chemical status of the surface water bodies by the RBDs - RBMP 2016-2021

River Basin District/Chemical status	Danube	Black Sea	East Aegean	West Aegean
High	165	45	49	63
Good	6	9	7	3
U	85	11	255	117
no data	0	140	0	0
Total	**256**	**205**	**311**	**183**

Significant management issues

The significant pressures delineated by the above-mentioned conceptual method in RBMP and the third Mid-term review of significant water management issues - 2021 identify among the water management important problems the following ones depicted below.

- Contamination with biogenic elements

Main causes of this pollution are: *Erosion* - in Bulgaria 1.7 million ha are affected by erosion, out of which 0.4 million ha - to a high and very high degree; *Farming* - during the last decade agricultural production in Bulgaria has increased by over 50%, and meat production by 48%. Cultivated land is treated with artificial fertilizers and preparations for plant protection. During the period 2010-2019 the average nitrogen mineral fertilizers used dose in DRBD is 120 kg/ha, in BSRBD - 123 kg/ha, in EARBD - 75 kg/ha, and in WERBD - 31 kg/ha, so that the treated area increased respectively by 56%, 67%, 112%, and 55% compared to 2010.

The average dose of mineral phosphorus fertilizers used for the same period is: DRBD - 11.4 kg/ha, in BSRBD - 12 kg/ha, in EARBD - 7 kg/ha, and WERBD - 3 kg/ha, so that the treated area increase is respectively by 120%, 137%, 201%, and 119% compared to 2010. Significant agricultural pressure on the quality and quantity of surface waters in Bulgaria exerts animal husbandry - raising birds, pigs and cattle in farms, which produce significant amounts of waste water; *Wastewater from settlements and industry* - the share of the population connected to sewage and wastewater treatment plants (WWTPs) is an indicator, refer to Figure 5. The population in Bulgaria connected to public sewage is 76.3% with relatively small regional differences, while those connected to WWTPs are 66.7% with the Danube and Black Sea RBDs leading the way. Pursuant the provisions of Directive 91/271/EEC, the construction of WWTPs for another 123 agglomerations for 2000 units/population is planned as follow: in DRBD, 53, in BSRBD, 119, in EARBD, and 37 in WERBD. Tourism exercises significant pressure in RBRM, as well as intensive cultivation of aquaculture in fishponds mainly in EARBD and WERBD.

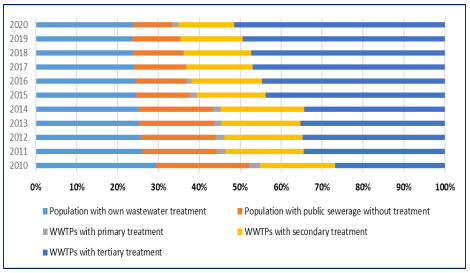

Figure 5. Population with public sewerage without treatment and wastewater treatment plants (WWTPs) in the period 2010-2020

- ***Organic pollution*** - the monitoring of BOD_5 results analysis indicates excesses in a relatively large number of SWBs in Bulgaria, with slight decrease trend in the multi annual values. The analysis of issued permits indicates that in BSRBD over 82%, in EARBD over 79% and in WERBD over 99% of catchment permits of BOD_5 are due for domestic wastewater. The situation is similar for the DRBD, where biogenic pollution exceeds organic pollution.
- ***Chemical pollution*** *(priority substances, specific and other pollutants)* due to such sources as farm related pesticides and plant protection preparations; industrial and household atmospheric emissions; wastewater discharge from industrial sources, waste landfills, old industrial areas and mine waters with contamination risks with specific pollutants (including radiation pollution) and with priority substances. As far as *the category river* in DRBD is concerned, specific pollutants affected 29% of the surface waters (the river beds of rivers Iskar, Ogosta, and Yantra being the most affected) and out of 13% of EARBD and WERBD. While of *category lake* - 4% in EARBD and 13% in WERBD.
- ***Water intake pressure*** is determined by the permits regime to secure the water users needs which may have a negative impact on the available surface runoff and, in particular, on water ecosystems. The trend of water intake from surface water sources in Bulgaria for the period 2010-2020 is presented in Figure 6.

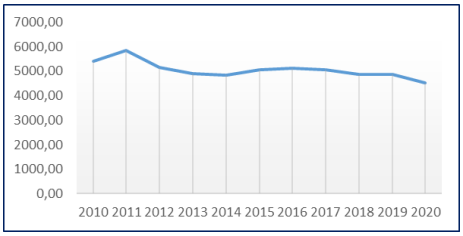

Figure 6. Surface water withdrawal in Bulgaria during the period 2010-2020

The largest share of granted permits for water consumption in Bulgaria are those for electricity production and cooling, while in relation to other sectors the leading one is fish aquaculture farming with 33.7%, followed by irrigation with 29%, drinking - domestic water supply with 18.2%, and industry with 14.2% (Figure 7).

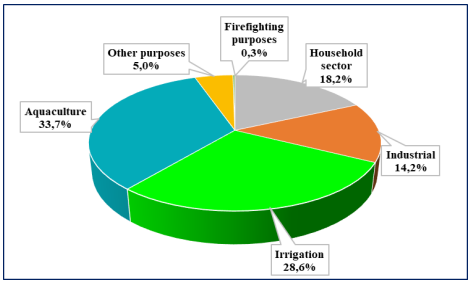

Figure 7. Permitted limits for water withdrawal from surface water sources in Bulgaria by 2022

The pressure from water intake on surface water in RBMP is based on a research report by the National Institute of Meteorology and Hydrology (NIMH) on the annual average national and regional (basin) resources, as well as data from the Basin Directorates on abstraction at the water body level. The pressure is classified in the following categories - from 0 to 3%; from 3 to 15%; from 15 to 20%; from 20 to 25%; from 25 to 30% and over 30%.
According to the second RBMPs, a total of 549, or 57.5%, of the surface water entities are exposed to water intake pressure, which according to the RBDs are shown in Figure 8.

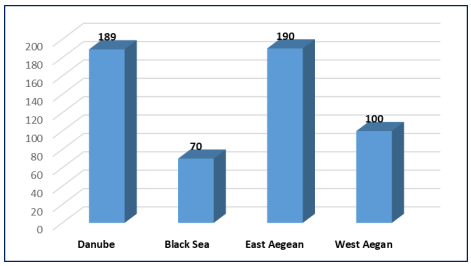

Figure 8. Surface water bodies under pressure from water withdrawn

The RBMPs 2016-2021 lack water user's security assessment and the water shortages, for which a summary assessment was produced in 2022 by calculating the Falkenmark Index for dry year. The index values varying from 543 for the Black Sea River Basin District to 1135 m^3/person/year for the Aegean Sea basin and total for Bulgaria - 842 m^3/person/year, are below the indicative water shortage norm of 1700 m^3/person/year (Seymenov, 2022).

- ***Climate pressure*** - With the applied in the second RBMPs "Approach to Assessing the Pressures and Impacts on Surface and Groundwater from Climate Change and Assessing the Availability of Water for Economic Sectors" climate change is integrated into the process of determining the risk of climate pressures by assessing the effect of changes under RCP 8.5 (pessimistic) and RCP 4.5 (moderate) climate scenarios. The model results for both scenarios indicate trends for increasing autumn precipitation in Bulgaria and decreasing summer precipitations. Concerning the RCP 8.5 climate change scenario for steadily increasing greenhouse gas emissions in time, the projected runoff change trends in the long term are strongest for the period 2071-2100. The Figures 9 to 11 present the climate change intensity for each of the three periods (2013-2042; 2021-2050, and 2071-2100) within the RCP 8.5 scenario.

The established significant positive trends in the air temperature in Bulgaria and modified hydrothermal conditions in the agricultural areas (Shopova et al., 2022) are increasingly becoming the subject of scientific research, given the pressure from the water resources use.

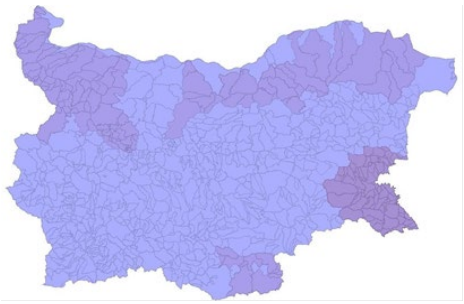

Figure 9. Intensity of expected climate changes for the period 2013-2042

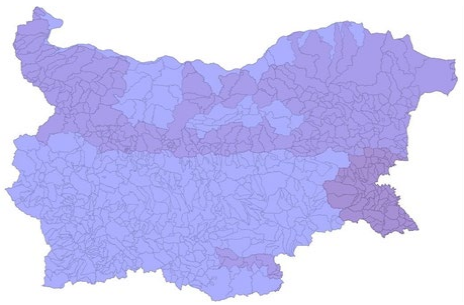

Figure 10. Intensity of expected climate changes for the period 2021-2050

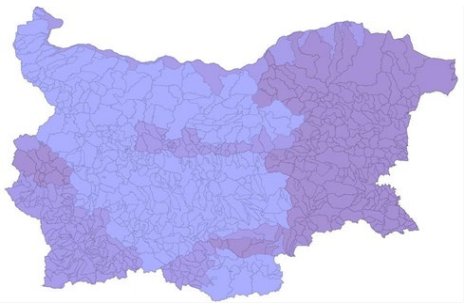

Figure 11. Intensity of expected climate changes for the period 2071-2100

Planned measures

Given the above approach, the updated PoM driving forces include the following key core measures to:

- ***urban territories*** - construction of new or modernization of existing WWTPs, protection of drinking and domestic water sources with introduction of secured zones and prevention of urban areas, transport and existing infrastructure pollutions;
- ***industry*** - construction of new or modernization of existing industrial WWTPs;

- ***agriculture*** - reduction agriculture generated biogenic elements and pesticides pollution, reduction of soil erosion and surface runoff deposits;
- ***energetics*** - improving the water entities hydrology morphological conditions (restoration of rivers, improvement of coastal areas, removal of hard embankments, restoration of the connection between rivers and floodplains, etc.), runoff regime improvement and/or determination of the minimum ecological runoff in rivers.

An extremely important measure is the implementation of efficient water use in irrigation, industry, energy and households. Complementary measures usually concern the implementation of monitoring, control and additional research, as well as the implementation of good agricultural practices, some prohibitions (e.g. for the construction of hydroelectric power stations) and the construction of facilities such as fish passages. The largest share is for the urban zones planned measures. For example, in the EARBD the measures share in urbanization is 50%, those planned for more than one driving force - 20% and for agriculture - 13%.

CONCLUSIONS

In Bulgaria, although with successfully introduced and applied methods and practices for integrated basin water management, there are still a number of gaps in the planning process.

The indicated management issues focus on surface water pollution and under-estimated water intake pressures in drought periods and require above all science-based approaches.

First of all, in order to boost the assessment credibility for pollution sources and relevant pollutants, and select appropriate measures, it is necessary to coordinate the scientific research results with available methodologies and upgrade them.

Since the quantitative status is an integral part of the water general state, in sake for planning objectivity and completeness, the European Commission requires actions in this field. It requires available water resources management assessment to find out the assurance degree for water users in different water supply periods in connection with climate scenarios. Based on existing scientific developments in Bulgaria, and considering changing conditions and water users' requirements, an approach for water balance assessments at the basin/sub-basin level with the definition of water efficiency targets should be both justified and applied. Considering the climate change pressure, independently or as part of the next RBMPs, is of particular importance the development of a management plan for water resources in drought conditions, a challenge for the scientific research community in Bulgaria.

Finally, the achievement of the WFD and the RBMP targets depends directly on the implementation of planned measures. In Bulgaria, this is generally hindered by: unsecured or delayed funding for investment measures (for example: for basic structure measures such as construction/upgrading of sewage systems), insufficient administrative capacity to control the measures implementation and non-implementation by the managing authority for investments or administrative measures (for example, non-fulfillment of permit conditions for surface water withdrawal).

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