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Water Management of cross-border waterbodies

Possibilities for joint cooperation in coping with the challenges

Darko Babunski, Zoran Markov
Iljco Jovanoski, Charalampos Skoulikaris,
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FACULTY OF MECHANICAL ENGINEERING

ARISTOTLE UNIVERSITY OF THESSALONIKI

SCHOOL of CIVIL ENGINEERING

Konrad-Adenauer-Stiftung
Office in Skopje
Risto Ravanovski 8
1000 Skopje, North Macedonia
T + 389 / (2) 3217 075
skopje@kas.de

Wilfried Martens Centre for
European Studies
20 Rue du Commerce
1000 Brussels, Belgium
T + 32 / (0) 2 300 80 04
info@martenscentre.eu

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Editors:
Babunski Darko, PhD, Professor at the Faculty of Mechanical Engineering-Skopje
Markov Zoran, PhD, Professor at the Faculty of Mechanical Engineering-Skopje

Contributors:
Babunski Darko, PhD, Professor at the Faculty of Mechanical Engineering, Ss. Cyril and Methodius University in Skopje
Jovanoski Iljco, PhD, Expert in Waste Water Management, Ss. Cyril and Methodius University in Skopje
Markov Zoran, PhD, Professor at the Faculty of Mechanical Engineering, Ss. Cyril and Methodius University in Skopje
Skoulikaris Charalampos, PhD, UNESCO Chair of International Network of Water-Environment Centres for the Balkans (INWEB), Aristotle University of Thessaloniki
Tuneski Atanasko, PhD, Professor at the Faculty of Mechanical Engineering, Ss. Cyril and Methodius University in Skopje
Xenidis Yiannis, PhD, Professor at the School of Civil Engineering, Aristotle University of Thessaloniki
Zafirakou Antigoni, PhD, Professor at the School of Civil Engineering, Aristotle University of Thessaloniki

Coordination:
Norbert Beckmann-Dierkes
Daniela Popovska

Proofreading:
Perica Sardzoski

Design and Printing:
Vinsent Grafika DOO Skopje

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Abbreviations

BOD_5	-	Biochemical Oxygen Demand
CCTV	-	Camera recording of the pipeline insides
COD	-	Chemical Oxygen Demand
ETC/ INTERREG	-	European Territorial Co-operation
EU	-	European Union
EUR	-	Euro (currency)
fYROM	-	former Yugoslav Republic of Macedonia
GCF	-	Green Climate Fund
GCM	-	General Circulation Model
GIS	-	Geospatial Information System
GSP	-	Global Support Programme
HIPERB	-	Hellenic Plan for the Economic Restructuring of the Balkans
IPA	-	Instrument for Pre-accession
IPCC	-	Intergovernmental Panel on Climate Change
IPPC	-	Integrated Pollution Prevention and Control
JMD	-	Joint Ministerial Decision
MAFWE	-	Ministry of Agriculture, Forestry & Water Economy of North Macedonia
MDG	-	Millennium Development Goal
MoEPP	-	Ministry of Environment and Physical Planning of North Macedonia
MIRVAX	-	Monitoring and Improving of the rivers Vardar-Axios
North Macedonia	-	Republic of North Macedonia
MTC	-	Ministry of Transport & Communications
NAP	-	National Adaptation Plan
NAS	-	National Adaptation Strategy
NATO	-	North Atlantic Treaty Organization
OECD	-	Organization for Economic Co-operation and Development
PCE	-	Public Utility Companies
PHARE	-	Poland and Hungary: Assistance for Restructuring their Economies
PLC	-	Programmable Logic Controller

PPP	-	Purchasing power parity
RBMP	-	River Basin Management Plan
SAA	-	Stabilization and Association Agreement
SCADA	-	Supervisory Control and Data Acquisition
SDG	-	Sustainable Development Goal
SEE	-	Southeastern Europe
SfP	-	Science for Peace
UNDP	-	United Nations Development Programme
UNECE	-	United Nations Economic Commission for Europe
UNEP	-	United Nations Environmental Programme
UNFCCC	-	United Nations Framework Convention on Climate Change
UNESCO	-	United Nations Educational, Scientific and Cultural Organization
VAX	-	Vardar/Axios River
WFD	-	Water Framework Directive
WWAP	-	United Nations World Water Assessment Programme
WWTP	-	Wastewater Treatment Plant

Preface

Preface

This publication is a result of the long-lasting collaboration between professors and scientists from the Faculty of Mechanical Engineering at the Ss. Cyril and Methodius University in Skopje, North Macedonia, and the School of Civil Engineering at the Aristotle University in Thessaloniki, Greece. Over the last years, there was a continuous effort for joint actions and initiatives on issues related to the management of the water resources that are shared between the two countries. It is with honor to acknowledge that our joint cooperation efforts were recognized by the European Commission and bilateral research initiatives and workshops development were co-funded through various EU programmes.

The transboundary surface water bodies of Vardar/Axios River, Dojran/Doirani Lake and Prespa Lake have undoubtful importance at national and regional levels fostering economic prosperity and development, social integrity and environmental protection. The management of these waters at basin scale is a step forward for achieving closer cross-border cooperation and for promoting sustainable development. The outputs of this book demonstrate the current situation as well as the progress that has been conducted in the management of the transboundary waters of the two countries. Moreover, the provided material set the base for the Integrated Water Resources Management at basin scale and addresses further cooperation perspectives in the field of climate change adaptation and of Water-Energy-Food-Environment nexus. Hence, we feel that this book should contain both descriptive and informative sections that could be used for environmental educational purposes at both universities, but also to thoroughly depict our cooperation in different surroundings and backgrounds, as well as to shed light on future advancements.

The authors would especially like to thank the Skopje office of the Konrad-Adenauer Stiftung for the initiative to enhance the cross-border cooperation between the two higher education institutions, and the Wilfried Martens Centre for European Studies, for their assistance in preparing and producing this book.

The Authors

1

Introduction

1 Introduction

by Darko Babunski, Zoran Markov and Charalampos Skoulikaris

Water is a limited resource for which demand is growing practically everywhere. All human activities that require water, including domestic, industrial, agricultural, commercial, and urban sectorial activities, are conceived as conflicted activities since all these different users necessitate to satisfy their demands using the same resource. The adverse impact of climate change on water resources is an additional challenge that is bound to exacerbate the pressure on the water environment. In the case of international waters, the frequent non-convergent objectives among the riparian countries regarding the usage and development of their national waters proved to act as an inhibitor against the integrated management of the water resources at a transboundary basin scale. In transboundary basins, the downstream countries are usually directly dependent on the upstream waters, both in terms of quality and quantity, to cover their demands.

Almost all human activities produce wastewater. The continuous demand for water coincides with increased volumes of produced wastewater with the overall pollution load to be constantly increased on a worldwide scale. Polluted waters, produced from pollution from untreated wastewater, has a huge impact on human health, particularly in the developing world. At the same time, in the most highly developed countries, the vast majority of wastewater is released directly to the environment without adequate treatment. The 2030 Sustainable Development Agenda explicitly focuses on reducing pollution and improving the disposal, management, and treatment of wastewater. The 2017 United Nations Water Development Report (WWAP, 2017) is dedicated to wastewater that is characterized as an untapped water resource. The report clearly mentions that "In the face of ever-growing demand, wastewater is gaining momentum as a reliable alternative source of water, shifting the paradigm of wastewater management from 'treatment and disposal' to 'reuse, recycle and resource recovery'. In this sense, wastewater is no longer seen as a problem in need of a solution, rather it is part of the solution to challenges that societies are facing today. Wastewater can also be a cost-efficient and sustainable source of energy, nutrients, and other useful by-products. The potential benefits of extracting such resources from wastewater go well beyond human and environmental health, with implications on food and energy security as well as climate change mitigation."

Western Balkan countries, including the Republic of North Macedonia, have expressed a clear political objective to become part of the European Union (EU). In these countries, the harmonization of their national legislations to the EU *acquis* is the process that should be followed for a candidate country to be granted the status of an EU member state. The adaptation of the environmental sector in North Macedonia began with the adoption of EU laws and continued with the implementation of the necessary measures. Construction of new municipal wastewater treatment plants (WWTPs) in the region began at a modest level about 15 years ago, with a forecast to grow into one of the leading infrastructure areas to be invested in.

WWTPs usually have relatively high investment and operating costs, with processes that have high electricity consumption. WWTPs are mostly operated by Public Utility Companies (PCEs). The difficulties in funding the WWTPs calls into question the sustainability of such an investment. The selection of the most appropriate treatment technology in terms of investment and optimal operating costs is of great importance in the planning of such long-term investments.

WWTP treatment processes and technology cannot be unified, as each treatment plant should be following specific local socio-economic, technical, spatial, and climatic conditions such as: investment and operating costs, capacity, pollutants, and level of pollution, effluent quality, available technology, level of expertise of operators, availability of construction land and additional other indicators. For the correct choice of the most appropriate purification technology in a WWTP, it is necessary to take into account all local conditions.

1.1 Transboundary water resources

The more independent states a region has, such as the Balkan Peninsula, the interstate water resources problems and solutions are becoming more numerous and complex (Vujica, 1996).

Delineation of the boundaries across the Earth has been driven by political and strategic consideration, ever since the existence of the civilization. The ecosystem, including mountains, rivers, lakes, has been assigned to the jurisdiction of different states and administrative entities with little regard to their environmental cycles. However, freshwater and all the other natural resources do not understand human-made boundaries, and therefore require internationally coordinated actions for sustainable management. Luckily, in recent years, transboundary waters took a space in international dialogue, as issues of water and food security force, in order for the policymakers to have a more holistic view. Additional pressure is placed on the world's water reserves as a result of climate change and global change in general. So, it is of no discussion that it is about time for strengthening cooperation among neighboring countries and build peace amongst states (Ganoulis, et al., 2011).

The global increase of population together with the steady socio-economic development of emerging economies, and the subsequent increase in water demand in combination with the accelerated water pollution from various points and diffuse sources, means that transboundary water resources, located both on the surface (rivers and lakes) and in groundwater aquifers, are very important sources of water for different uses at global and regional scales, and form a significant part of the precious available water on earth. Although the total amount of water on earth is substantial, only a very small fraction of it is not saline and can be directly used by man. According to World Water Development Reports that official international organizations are conducting, this amount is only 2.5% of the total water available on Earth. When economically available renewable water resources are taken into account, global water availability is estimated at about 13 500km^3 per year, and it is only 2300m^3 per person per year. This is approximately 37% less than in 1970. About 60% of global river flow lies within transboundary river basins, the surface area which is almost half of the world's land surface. The significance of transboundary waters may be seen from the following data:

» 40% of the world's population lives within transboundary watersheds;
» 45% of the total land surface of our planet lies in this area;
» 263 major internationally shared basins are reported; approximately one-third of the 263 transboundary basins are shared by more than two countries;
» 145 countries have territory within transboundary river basins;
» 21 countries lie entirely within one transboundary river basin;
» More than 95% of the territory of 12 countries lies within one or more transboundary basins;
» 19 basins involve five or more different countries.

World global water quality crisis and the need for wastewater treatment plants

The identification of the issue for the need of WWTP is done through the following questions:

» Why is it important to build a WWTP?

Wastewater is generated from households, human and animal waste, industry, partly from stormwater and groundwater that infiltrates into the soil. Wastewater carries components (contaminants) that must be removed or reduced accordingly before the effluent is discharged. According to the existing legislation, the collected municipal wastewater should be treated appropriately before the discharge into the recipient, discharge to the ground, or reuse. When designing the technological process, the following questions are asked:

- » What level of treatment should be established to ensure an adequate level of environmental protection?
- » What type of processes and devices should be used to achieve this goal?

To answer these questions, an analysis of local conditions and needs, application of scientific knowledge and engineering practices will be made, taking into account the current national regulations and legislation. An overview of today's best techniques and technologies for wastewater treatment will be also made with an emphasis on the process of biological treatment with activated sludge.

Water supply and sewerage systems are one of the infrastructural pillars of modern society. It is a complete system that contains the treatment of drinking water and distribution to users, its utilization, collection of used wastewaters, its transport, treatment and return to nature.

1.2 Aim of the publication

The aim of the publication is to demonstrate the increasing potentiality of cross-border cooperation between North Macedonia and Greece for the management of their shared water resources. Water resources management at basin scales is an important step forward for integrated water resources management, an issue that is fostered by the Water Framework Directive of the European Union. At the same time, the threats derived from untreated wastewaters are commonly transboundary water-related problems that need to be resolve before producing conflicting situations.

Chapter 2 tries to shed light on the water resources management of the transboundary Vardar/Axios river basin located in the Balkan Peninsula and shared between North Macedonia and Greece. The main problems related to the management of the Vardar/Axios River were identified and comprised of political tensions, lack of closer cross-border collaboration, and the low quality of the upstream waters inflowing in the lower part of the basin. Currently, the new insights such as the significantly improved political relations, the gradual adaptation, and application by North Macedonia of the European Union's environmental legislation related to water resources, namely the Water Framework Directive, and the on-going investments in hydraulic projects focused on the treatment of wastewaters have put new standards regarding the management of the transboundary water resources and explicitly demonstrated within the chapter. European Union's funding opportunities for joint programmes and projects on water resources management should be used for the countries' cooperation enforcement and the sustainable management of the cross-border waters.

Chapter 3 focuses on the wastewater management and demonstrates the world global water quality crisis and the need of wastewater treatment plants. It also explicitly demonstrates the wastewater collection and treatment processes, a review of the utilized technologies, as well as provides information on the relative EU legislation about wastewaters. Moreover, it includes descriptive data on the current and ongoing wastewater treatment projects both in North Macedonia and Greece, with selective case studies to be demonstrated. Chapter 4 and Chapter 5 put emphasis on the wastewater management of the Dojran/Doirani Lake and Prespa Lake respectively. In both chapters, detailed information regarding the transboundary lakes status are given, as well as the identified pressures on the hydro system of each case study area. Data of the water quality status of the two lakes are also depicted within the chapters. Finally, the measures and actions for the protection of the waters are clearly mentioned.

Finally, Chapter 6 entitled as "Educating tomorrow's water managers: Experiences from regional student workshops" demonstrates the usage of the aforementioned chapters for promoting transboundary environmental education, with special emphasis to be given on the water resources management and the protection-amelioration of the quality of the surface water bodies that are shared between the two countries.

2

Overview of the situation with the Water management of the Vardar/Axios River in North Macedonia and Greece

2 Overview of the situation with the Water management of the Vardar/Axios River in North Macedonia and Greece

by Charalampos Skoulikaris and Atanasko Tuneski

Water is the key parameter for life creation and conservation. It is vital for all known forms of life, and it can be found in all of its states, i.e. liquid, gas, and solid, on the Earth; a planet also known as the Blue Planet because of the dominance of the water. The importance of water in human life is clearly demonstrated by human's settlements proximity to rivers and lakes to cover water supply and agricultural demands on water. Deltaic regions, for example, although having a coverage of 1% of the world's land area, host more than half a billion people, i.e. 7% of the world population (Ericson, et al., 2006). Moreover, the majority of the megacities around the world are located on rivers' delta or they are cross-cut by rivers, with New York and the River Hudson, Paris and the River Seine, London and the River Thames, Buenos Aires and the River de la Plata to be characteristic examples. The rapid and uncontrolled growth of the megacities in the developing world, nevertheless, has posed major water planning and management challenges such as pollution issues, inefficient and unequitable water allocation, and problematic wastewater and stormwater management (Varis, et al., 2006). The closeness to the rivers facilitated also navigation purposes, an issue that led humans to follow the courses of rivers during migration periods (Bertuzzo, et al., 2007).

The significance of the water is sustained by all the modern initiatives fostering the sustainable development. At the beginning of the 21st century, the United Nations (UN) member states agreed on the eight Millennium Development Goals (MDGs). MDG 7 focused on ensuring environmental sustainability with the water having a pivotal role, however, the water is connected with issues such as sanitation, health, poverty alleviation, and disaster reduction which are denoted within the other goals (Lenton, et al., 2008). The most recent 2030 Agenda for Sustainable Development calls on countries to begin efforts to achieve 17 Sustainable Development Goals (SDGs) over the next 15 years. SDGs along with their thematic targets are considered as the state-of-the-art directions' framework for the sustainable development of our planet (UN, 2015). SDG 6 is related to clean water and sanitation, however the multidisciplinary of the water sector cross-cuts almost all the other goals, such as SDG 7 Affordable and Clean Energy, with all energy forms requiring water to varying degrees, SDG 11 Sustainable Cities and Communities, with water being a basic service, SDG 13 Climate Action, with water-related disasters to be attributed to climate change and SDG 15 Life on Land where activities taking place on land, e.g. agriculture, to depend on water quality and quantity (UN, 2018). The proposed goals and targets interconnection in a form of a network where links among goals exist through targets that refer to multiple goals is also mentioned in the literature (Le Blanc, 2015).

Water resources management and allocation is a multifactor equation that needs to be addressed, with the current competing demands, such as water supply, agricultural irrigation, hydropower generation, and ecosystems preservation, to be directly affected by demographic and climate changes drivers that increase the stress on water resources (Skoulikaris, et al., 2018); (Kolokytha & Skoulikaris, 2020). The solution of the equation is getting even more complex when the scale factor is changing, i.e. passing from national to international water bodies. In this case, the management of transboundary waters requires subtle approaches to succeed on i) political willingness for cooperation and ii) communication channels among decision-makers, scientists, stakeholders and iii) effective exchange mechanisms of data and information (Ganoulis & Skoulikaris, 2013). The importance of cooperation on transboundary water resources management is denoted by the 688 transboundary water agreements that have been identified until the beginning of the 21st century covering 113 basins (Giordano, et al., 2014). Gerlak et al. (2011) in their research analyzed 287 transboundary water agreements and they concluded that almost half of the agreements that include data and information exchange were signed in the last 50 years.

Transboundary cooperation is essential for achieving sustainable development and use of water bodies, with 153 countries sharing rivers, lakes, and aquifers with other countries (UN, 2018). SDG target 6.5 focused on the implementation of integrated water resources management (IWRM) is anticipated as a roadmap for transboundary cooperation, cross-border development, and conflict resolution. The common management of international water resources is also proposed by the First (UNECE, 2007) and Second (UNECE, 2011) Assessment of transboundary rivers, lakes and groundwaters reports fostered by the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes, also known as the Water Convention (UNECE, 1992). Aiming at designating the importance of transboundary waters, these two reports include a thorough analysis of the pressure factors, the quantity and quality status, as well as responses and future trends of transboundary waters. The progress that was achieved in terms of integrated water resources management at basin scale among riparian countries for the period between the publications of the two reports is also stated in the 2nd Assessment Report.

The collaboration at a transboundary river scale is a priority issue of the European Union (EU) environmental policy and particularly of the Water Framework Directive (WFD) (European Parliament, Council of the European Union, 2000). WFD is the EU's legislative instrument for the management of water resources focusing on sustainable development, integrated management, and subsidiarity (Kallis & Butler, 2001) with the overall goal of "good" and "non-deteriorating status" for all types of waters. The implementation mechanism of the directive is the River Basin Management Plans (RBMPs) where information about the status, pressures, and proposed measures for the amelioration of degraded water are mentioned for each basin. In the case of transboundary waters, i.e. transboundary river basins, WFD fosters riparian cooperation to form common RBMPs. In particular, Article 13 of the directive states: "In the case of an international river basin district extending beyond the boundaries of the Community, Member States shall endeavor to produce a single river basin management plan". Based on the cooperation convergence among the riparian countries, the transboundary river basins are classified as (Skoulikaris & Zafirakou, 2019) i) International river basins with an international agreement-convention & a River Basin Organization & international River Basin Management Plan (e.g. the Danube River Basin), ii) International river basins with an international agreement & coordination body & no international River Basin Management Plan (e.g. the Rhone River Basin), iii) International river basins with an international agreement & no coordination body & no international River Basin Management Plan (e.g. the Vistula River Basin), and iv): International river basins with no international agreement/convention & no coordination body & no international River Basin Management Plan (e.g. the Vardar/Axios River Basin).

In South-Eastern Europe (SEE), also known as the Balkan Peninsula, and by excluding the Danube basin area, there are fourteen transboundary basins and four transboundary lakes that are shared between two or more riparian countries (Ganoulis, J; Zinke Environmental Consulting, 2004). Greece shares with its neighboring countries the waters of five rivers and two lakes. In particular, it receives the waters (downstream country) of four international rivers, namely Maritsa/Evros/Meric River, Mesta/Nestos River, Struma/Strymonas River, and Vardar/Axios River, where the waters after being accumulated with those drained in the Greek part of the basins are outflowed in the Aegean Sea (Kolokyhta & Skoulikaris, 2019). At the same time, Greece is the upstream country of the Vjosa/Aoos Transboundary River that discharges in the Adriatic Sea (Kolokyhta & Skoulikaris, 2019). The transboundary Prespa Lake is shared with Albania and North Macedonia while the Dojran/Doirani Lake is shared between North Macedonia and Greece. Focusing in North Macedonia, apart from the Dojran/Doirani Lake, the country shares the waters of an additional lake, namely the Ohrid Lake, with its neighboring country to the west - Albania. In terms of international river basins, within North Macedonia's territory are located the aforementioned Vardar/Axios river basin, the headwaters of the Strumica River which is the major tributary of the transboundary Struma/Strymonas River, and the southern parts, namely the Black Drin River, of the transboundary Drin River. As stated by Yevjevich (1995), the more independent states a region has, such as the Balkan Peninsula, the interstate water resources problems and solutions are becoming more numerous and complex.

The aim of this chapter is to demonstrate the evolution of the management of the waters of the Vardar/Axios transboundary river basin through the years and through different political situations. The chapter aims to demonstrate the major conflict situations related to the management of the waters between North Macedonia and Greece, as well as to present the recent positive advancements in the management of the basin. For that purpose, Section 2 provides a detailed description of the Vardar/Axios case study and denotes the major pressures on the water environment at the national level from both countries. The review of the management of the basin at a transboundary scale, including common cooperation programmes/projects, the new political agreements, and the identified in the past cross-border problems are thoroughly being presented in Section 3. Section 4 presents the current legal framework on water resources management and the way that past identified problems are led to be resolved. Section 5 includes the perspectives of closer cooperation between the two countries aiming at the integrated management of the Vardar/Axios river basin. Finally, within the conclusions, Section 6, an overall synopsis of the chapter's outputs is presented.

2.1 Description of the Vardar/Axios River Basin

The Vardar/Axios river basin is one of the fourteen Sub-Danubian transboundary river basins (Ganoulis, J; Zinke Environmental Consulting, 2004) of Southeastern Europe (SEE). Until 1992 only two countries shared Vardar/Axios river basin, Yugoslavia and Greece (in the further text Greece), however, the division of Yugoslavia into seven new countries resulted in the sharing of the basin by Serbia, Kosovo, North Macedonia (in the further text North Macedonia) and Greece. Kosovo and North Macedonia share the Lepenec River, which is a 75 km long tributary of the Vardar River located in the northern part of the basin. Serbia shares with North Macedonia the Pcinja River, which is one of the left-bank tributaries of the Vardar River. Pcinja has a length of 135 km, with almost 100 Km to lie within North Macedonia (Zlatkovic, et al., 2011). Because of the small size of these tributaries, in comparison to the rest part of the basin, the analysis that is conducted in the Chapter is focused on the waters shared between North Macedonia and Greece. Hence, hereinafter the assumption that the Vardar/Axios river basin is shared only between North Macedonia and Greece is considered. In SEE region, also known as the Balkans Peninsula, there are also four transboundary lakes (Ganoulis, J; Zinke Environmental

Consulting, 2004), with the Dojran/Doirani Lake to be shared between North Macedonia and Greece, nevertheless the lake forms part of the Vardar/Axios watershed. More detailed analysis of the specific lake is conducted in Chapter 4.

The Vardar River has its source at a mountainous area between Albania and North Macedonia, namely Shara massif, and follows a north-east direction. The river catchment covers approximately 88.2% of North Macedonia while the river's main course splits the country into almost two equal shares, the eastern and western parts of the basin. After 302 km the river enters Greece where its name is changed to Axios. Following a north to south direction of 87 km Axios river outflows into the Aegean Sea (Mediterranean Sea) at Thermaikos Gulf (Greece), Figure 2-1.

The relief of the catchment in the North Macedonia part is predominantly hilly-mountainous. In the northwest, the mountains have altitudes of more than 2,500 m a.s.l. and about 2,000 m a.s.l. in the eastern part (Ganoulis, J; Zinke Environmental Consulting, 2004). The Greek part of the basin is characterized by very low altitudes, except for the mountainous areas at the western part of the river, with the highest peak at ~1,650 m a.s.l., and at the northeastern boundaries of the basin. By taking into consideration the elevation at the Greek-North Macedonia borders, i.e., the entrance point of the river in Greece, is lower than 50 ma.s.l. and the river's length until the estuaries is 87 km, Table 2-1, it can be concluded that due to the negligible longitudinal incline of the downstream part of the basin is a flood-prone area. The vulnerability of the downstream part of the basin to flood events is clearly demonstrated in the Flood Risk Management Plant of the Water District Central Macedonia (Greece10) in Greece (Special Secretariat for Water, 2018), where the Axios river belongs to. The characteristics of the Vardar/Axios river basin are presented in Table 2-1 (Skoulikaris & Zafirakou, 2019), (UNECE, 2011).

Table 2-1 Characteristics of Vardar/Axios river basin

River basin	Riparian countries	Area in the country (km^2)	Country's share (%)	Mean elevation (m)	River length (km)	Annual precipitation (mm)	Annual discharge** (×10^{6}m^3)
Vardar/ Axios	MK	19,737	88.7	1124	302	707	3,385
	GR	2,513*	11.3	180	87	450	800
	Total	22,250			389		4,185

*Based on data on the River Basin Management Plan of the Water District of Central Macedonia (GR09) (Special Secretariat for Water, 2013), the basin extends in Greece is 3,327 km^2 since it includes the neighboring western Loudias basin.

**Averaged for the (period 1961-1990)

The flow regime is characterized by average flows during the 70s, a wet period from 1980 to 1985, and then a dry period from 1986 to 1994 (Popov, et al., 2014), (Milovanovic, 2007). According to Van Gils & Argiropoulos (Van Gils & Argiropoulos, 1991), the average yearly flow of the Vardar/Axios River near the border was about 150 m^3/s, with the average monthly flow to vary between 20 m^3/s and 250 m^3/s in summer and spring periods respectively. Periods with peak flows of over 500 m^3/s as well as with flows below 20 m^3/s was a frequent phenomenon. Based on more recent data, in the period 1996–2003, the maximum levels of river discharge close to the boundary city of Gevgelija in North Macedonia and in the delta's estuaries in Greece were equal to 192 m^3/s and 106 m^3/s respectively (Milovanovic, 2007).

Figure 2-1 Illustration of the Vardar/Axios river basin and its principal hydrographic network.

The main tributaries and their respective hydrological characteristics of the Vardar/Axios River are presented in Table 2-2 (Ramani, et al., 2014), (Spirkovski, et al., 2007), (Ganoulis, J; Zinke Environmental Consulting, 2004). A descriptive illustration of the river basin, as well as its hydrographic network, is given in Figure 2-1

Table 2-2 Vardar/Axios main tributaries' characteristics

River	Country	Watershed (Km^2)	Length (Km)	Average discharge (m^3/s)	Annual discharge ($\times 10^6 m^3$)
Crna	MK	5,093	863	8.68	1,170
Treska	MK	2,068	138	2.4	762
Pcinja	MK	2,800	135	2.6	397
Bregalnica	MK	4,307	211.5	6.36	444
Kotza Dere (Mega Rema)	GR	140	42	0.125	-
Gorgopis (Seirios)	GR	-	70	0,278	-
Vardarovasi	GR	-	102	-	-

In terms of land uses, the main forms of land use of the whole basin are cropland and forests (UNECE , 2011). Focusing on the upstream part of the basin, i.e. in North Macedonia, agricultural land covers 50.77%, forests 40.15%, water (rivers and lakes) 3.44%, and other uses 5.64% of the basin (Ganoulis, J; Zinke Environmental Consulting, 2004). The downstream part of the basin, i.e. the Greek part, agricultural land (56.74%) covers the largest part of the basin, while 37.89% of the total area is covered with forest.

The environmental protected area of Axios River's delta

At the beginning of the 20th century, the Axios used to flow into a few kilometers to the south-west of Thessaloniki. Due to the continuous sediment transfer within the Thermaikos gulf and in order not to cut off Thessaloniki's port access to the sea, in the 1930s, the riverbed was transferred through technical works, into its present location. Since then and together with the extensive irrigation reclamation works of that era, the river delta has become an extended deltaic plain. The aforementioned hydraulic works together with similar works at the estuaries of the neighbouring rivers resulted in the current formation of the coastal system. This area is designated as one of the most important ecosystems in Greece, that includes the mouths of the rivers Axios, Aliakmon, Gallikos, and Loudias that all discharge into Thermaikos Gulf, the two old riverbeds of the Axios, and the Kalochori Lagoon, Figure 2-2 (Vokou, et al., 2018).

Because of its considerable ecological importance, the area has been included in the Natura 2000 network of European ecological regions. At the same time, it is protected by the Ramsar International Convention on wetlands. The largest part of this protected area has been listed as a National Park, namely National Park of the Delta of Axios – Loudias – Aliakmon through Joint Ministerial Decision (JMD) 12966/2009. The National Park covers an area of 33.800 hectares and is a system of river estuaries, marshes, lagoons, and salt flats, which makes it an ideal biotope for many species of wild animals, birds, and plants. In particular 295 species of birds, i.e. 66% of the species observed in Greece, 350 species and subspecies of plants, 40 species of mammals, 18 species of reptiles, 9 species of amphibians, 7 species of invertebrates, and 25 habitats, of which two are priority habitats on a European level, have been identified in this protected area (Vokou, et al., 2016).

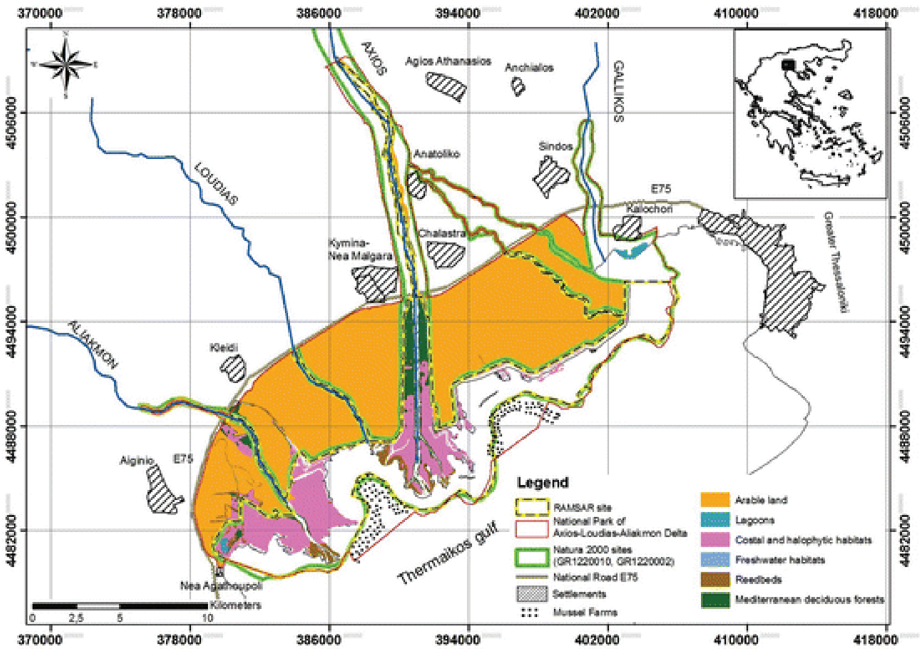


Figure 2-2 The Axios, Aliakmon, and Gallikos Delta complex and the borders of the protected area under different protection schemes. (source: (Vokou, et al., 2018))

2.2 Demographic characteristics and pressures on the environment

The Vardar River is located across North Macedonia; it is the major river from the northwest to the southeast border of the country. It has a watershed of 20.400 km^2 and an average elevation of 793 m, with an average discharge of 45 m^3/s and an annual discharge of 4565 million m^3. The Vardar River Valley is the main hydrological drainage system with more than 95 % of the country's catchment area. According to the topography, geology, hydrology characteristics, and the political territorial system, the river has been divided into some sections as for the water potential.

Axios river is a unique water resource for the irrigation of the fertile plain of Thessaloniki, it forms with the Greek river Aliakmon a very important delta, protected by the RAMSAR Convention, while it is the biggest polluter of the closed Bay of Thessaloniki.

Axios river basin is attached, for administrative purposes, to the Region of Central Macedonia and its watershed covers areas of the Regional Units of Kilkis, Thessaloniki, Pella, and Imathia. Based on the 2001 and 2011 census, the permanent population within the Greek part of the basin was 209,899 and 201,621 inhabitants respectively, presenting a small decrease of -3.9% (Special Secretariat for Water, 2013).

The water of the Vardar/Axios River in Greece is used for irrigated agriculture (63%), water supply and industrial use (15%), drinking water (12%), and fish ponds (11%). Hence, agriculture is by far the more important user of this resource. Regarding the mankind point and distributed pressures on the environment and on the water resources, these are designated to the following categories:

- Urban wastewater
- Industry
- Livestock
- Landfills
- Mines-Quarries
- Aquaculture, and
- Agriculture

Starting with the urban wastewater, within the Axios River Basin there are 3 agglomerations of Priority B (in the cities of Alexandria, Giannitsa, Kilkis), all provided with collecting systems connected to Waste Water Treatment Plants (WWTPs). Moreover, there are numerous Priority C settlements that are provided with adequate collection systems and served by WWTPs. The WWTP of Koufalia, for example, which is located within the Axios delta, has as an effluent recipient the Vardarovasi River, i.e. a tributary of Axios River. At this point it should be mentioned, that although Thessaloniki does not belong to the Axios Basin, it is the only A Priority Agglomeration and outlets its treated wastewater within the Thermaikos Gulf.

As for the pressure derived by industrial activities, within the Axios basin there are 89 industrial units, with 8 of them to be designated as IPPC units, i.e. to be controlled under the Directive 2008/1/EC concerning integrated pollution prevention and control (the IPPC Directive). The majority of the industrial units of the basin fall under the class of food and beverage (including the oil mills), while a significant number of plants are engaged in textile materials and products.

As the pressure from livestock is concerned, the identified 19 pig farms units of the basin (Special Secretariat for Water, 2013) within the point pollution sources, as the wastewater is not suitable for fertilization, therefore, disposal and dispersion on the fields is not an option. On the contrary, effluents from the numerous poultry units and cattle farm units end up in the fields for soil improvement or further treatment, disposal, and eventual use for various purposes. Thus, the significant livestock activity contributes about 39% of the total livestock organic load produced in the Water District of Central Macedonia in Greece. In the coastal water bodies of the Axios River, numerous aquaculture facilities operate. The majority of these are related to shellfish aquacultures and are located in depths of 8÷20 m within 1÷2 km from the coast within the coastal water bodies of the Thermaikos Gulf.

Additional pressure on the environment is also produced by landfills. In the Axios basin, there are 2 landfills, namely those of Kilkis and Giannitsa, which are in operation. Based on the RBMP Greece10 (Special Secretariat for Water, 2013), the Uncontrolled Waste Dumping Sites of Axios Basin have been restored. In regard to mining and quarry activities, currently, there are seven quarries (inert materials and marbles) and one red clay exploitation site. However, these do not present a significant pressure on the waters.

Finally, since agriculture is the primary activity in the area, significant pollutants flow into the water surface and groundwater bodies. Nutrient accumulation results in surface water eutrophication and deoxygenation phenomena. Pressures on groundwater bodies affect their natural function and groundwater level lowering is a common phenomenon. However, human activity is concentrated mainly on granular aquifers that include impermeable horizons, which act as filters retaining pollutants and also as dry barriers preventing pollutants' transfer to deeper aquifers. Therefore, a very small fraction of pollutants produced by human activities end up and affect the chemical status of the groundwater bodies of the basin.

2.3 Review on water management of Vardar/Axios River

2.3.1 Background information

The ancestor on the management of the Vardar/Axios River is the agreement of the 31st October 1959, between Yugoslavia and Greece, which shed light on issues related to the water management of Vardar/Axios River, Doirani Lake, and Prespes Lakes. The agreement foresaw the establishment of a Permanent Greek-Yugoslav Hydro economy Committee with emphasis to be given on the identification of potential problems and on the hydro economy project (Tsavdaridis, 2013). The agreement described in detail the selection of members and the duties of the Committee and provided detailed information on future technical projects within the river, as well as provided the ground for the exchange of meteorological, hydrologic, and geological data. The agreement ended due to Yugoslavia's fragmentation and it was officially terminated in 1991 when North Macedonia declared its independence. From 1991 till very recently, minor notable efforts were conducted for the establishment of a new agreement on the management of the transboundary waters between the two riparian states, mainly due to the North Macedonia naming dispute.

2.3.2 Identified cross-border problems

The main identified problems in the management of the Vardar/Axios waters focus on water quality issues. Both bibliographic sources and international reports designate the degradation of the river's water quality, mainly in the part of the basin that lies in North Macedonia and in the lower Greek part of the basin. However, the very recently constructed hydraulic projects as well as those that are currently under development started changing/ameliorating the water quality status of the river.

2.3.2.1 Water-related problems designated in the literature

In a research that was conducted in the early 1990s, using the results of monitoring in twelve stations over the time period 1984–1990, within the Thermaikos gulf, it was demonstrated the increased pollution loads to the estuaries of Axios River (Ganoulis, 1991). In all these stations temperature, salinity, pH, dissolved oxygen, nitrites, nitrates, ammonia, phosphates, silicates, heavy metals, total coliforms, and E-coli have been measured in the water column with seasonal frequency. The outputs demonstrated that there is a general trend in water pollution increasing from south to north and from the open sea to the Fstriver's estuaries, an issue that reflected increased pollutant loads from the coastal cities and towns in the northern part of the gulf and from the rivers' flow.

Karageorgis et al. (Karageorgis, et al., 2003) in their water and sediment quality assessment investigated the environmental pressures in the watershed of Axios River. To do so, they used a) long data series of water discharges and nutrients (nitrate, nitrite, ammonium, and phosphate) collected in three sampling sites in the Greek part of the basin, b) dissolved and particulate trace metal concentrations time series, and c) surface sediments data. They concluded that the extensive use of inorganic fertilizers is reflected in the Axios River water quality. Particularly, nutrient over-enrichment occurs during the low flow periods and during autumn–winter. This seasonal variability is linked to the agricultural activities and the domestic wastewaters that are released untreated (or partly untreated) in the river. Additionally, heavy metals (dissolved and particulate) in river water and sediments appear to be elevated. A significant part of these metals originates in ophiolite complexes and other heavy-metal rich formations that are abundant in the Axios River catchment. However, smelting industries in MK should be considered as primary point sources of heavy metals in the area.

Based on long-term (from 1979 to 2003) water quality parameters, such as nitrate, nitrite, ammonium, total phosphorous, BOD_5, Cd, Cr, Zn, Pb, as well as data relevant to the river discharges from 22 sampling stations distributed in both parts of the basin, the outputs demonstrated significant water quality issues (Milovanovic, 2007). The identified heavy metal pollution was attributed to the industries located in the northern and central parts of North Macedonia and it was connected to the disposal of their solid waste near the river bed and the discharge of the untreated industrial wastewater within the river. The degradation of the water quality was also connected to the discharge of untreated domestic wastewaters of the North Macedonia's main cities in the river (increased ammonium observations), while the observed nutrient pollution derived from the agricultural runoff from cultivated areas at both parts of the basin.

A similar study was carried out based on data at 27 sampling points both in the river's main course and its major tributaries for the sampling period June–September 2011 (Popov, et al., 2014). The study investigated the distribution of fifty-six elements related to water quality and the authors used a factor analysis methodology for creating four factors. Three factors consisted of elements that occur naturally in the river water and one factor consisted of anthropogenic elements. The analysis of the data and the methodology implementation demonstrated increased values for Cu and Zn, which are toxic to the environment and dangerous to human health. However, this increase was attributed by the authors to the river natural process. On the other hand, the showed correlation between Cd, Ga, In, Pb, Re, Sb, and Tl are connected to anthropogenic activities, mainly to industry, within the basin, with all these elements to represent a group of potentially threatening elements for human health and the environment.

2.3.2.2 Water-related problems mentioned in the Water Convention

Based on the 1st Water Convention Report (UNECE Geneva, 2007) the quality of the surface waters was classified as "good/moderate", i.e. the water is appropriate for irrigation purposes, but can be used for water supply only after treatment. The more recent 2nd Water Convention report (UNECE, 2011) indicated that the main pressure on water resources in terms of quality stems from agriculture (crop production and livestock), which is concentrated in the river valleys of Pelagonija, Polog, and Kumanovo, as well as in the whole Bregalnica catchment area. The aquatic ecosystem is also affected by the mining and quarrying activities, in particular, located in the catchment area of the eastern tributaries (rivers Bregalnica and Pcinja). The metal industry at Tetovo and heavy metal industry at Veles, as well as the presence of the chemical industry, petroleum refineries, and the pharmaceutical industry at Skopje, are additional pressure factors.

The treatment and disposal of solid waste and wastewater is an addition of significant pressure on the water resources. Based on data of 2011 (UNECE, 2011) although the existence of controlled landfills for solid wastes from bigger cities, there are also numerous illegal dumpsites for solid waste from the villages. At the same time, the sewage waters are directly outflowed in the Vardar River and its tributaries without any treatment, with the only properly functional wastewater treatment plant, is located at Makedonski Brod, in the Treska River catchment. Overall, the organic matter from wastewater discharges as well as the other sources of pollution has a transboundary impact and it was a conflict situation between the two countries.

2.3.3 Major funded programmes/projects for the Vardar/Axios

Due to the naming dispute between the two countries, the major cooperation projects on the waters of the Vardar/Axios Rivers are dated back to the late 1990s-early 2000s, i.e. few years after the independence of North Macedonia and before the period of the increased name conflicts.

Based on literature data (Ganoulis, J; Zinke Environmental Consulting, 2004) under the PHARE Cross Border Co-operation Programme MK/GR for the year 1997 (Sub-project MA 9707-02 “Environmental Protection”) the project “Automatic Monitoring Stations Downstream the Vardar River to Monitor Pollution Quantities by Various Parameters” was funded with 1.6 million Euros. The aim of the project was to provide continuous monitoring information on the water quality status and to open the possibility of rapid action against potential polluters. Two monitoring stations were set up in Taor and Demir Kapija in 2002 in order to collect real–time information on the water level, temperature, pH, turbidity, conductivity, dissolved oxygen, nitrites, nitrates, phosphates, heavy metals through total toxicity, total organic carbon. The station in Taor has been completely destroyed in 2007 and the station in Demir Kapija is completely rehabilitated, modernized, and upgraded through a NATO Science for Peace project described in detail below.

On the basis of the collected information, the Ministry of Environment in North Macedonia would take the consequent measures to mitigate the river’s pollution. The same year and under the same umbrella programme for North Macedonia two additional projects were funded (with about 2 million Euros). The objectives of the first project entitled "Institutional Strengthening and Capacity Building" was to assist the Ministry of Environment of North Macedonia to establish the proper capacity, i.e. adaptation of national legislation to the Water Quality Framework Directive and the Integrated Pollution Prevention and Control Directive, to deal with environmental protection, including water protection. Among the objectives of the second project entitled "Wastewater, water quality, and solid waste management" were the National Waste Water strategy development and Waste Water Management system for Skopje. In 1999, an additional PHARE Programme for North Macedonia was initiated to finance the project entitled "Strengthening to the Ministry of Environment to adapt environmental legislation to the Community acquis" as well as the project "Environmental awareness-raising, improvement of communication and environmental monitoring".

More recently, under the European Territorial Cooperation (ETC), broadly known as INTERREG, various common research projects between North Macedonia and Greece were financed to support the EU Cohesion Policy and to provide a framework for the implementation of joint actions. In particular under the INTERREG Instrument for Pre-Accession Assistance IPA Cross Border Cooperation Programme "Greece - Republic of North Macedonia 2014-2020" and the Priority Axis "Protection of Environment – Transportation" the following projects, Table 2-3 were financed aiming at the management of the waters of the Vardar/Axios river basin.

Table 2-3 North Macedonia-Greece INTERREG funded projects for the period 2014-2020

Programme	Title of the project	Project objectives
INTERREG IPA "GR - Republic of MK 2014-2020"	Sustainable management of cross-border water resources (AQUA-M II)	• Improve the river's water quality. • Establish a permanent technological network for the 24/7 monitoring of specific water quality parameters. • Establish an operational cooperation network for the prevention, protection, and immediate action in case of emergency and potential threats among local authorities of the cross-border area and scientific experts. • Improve cooperation among public and private stakeholders as well as the society and the local population of the cross-border area for the protection of the river.
INTERREG IPA "GR - Republic of MK 2014-2020"	Protection of water resources by reducing the human environmental footprint (umbrella)	• Reduction of the environmental footprint of human activities with sustainable use of natural water resources in ecosystems of the cross-border area. • A halt of the overexploitation and degradation of the natural water resources, focusing on water pollution, water stress, overconsumption of water, and the vivid involvement of the citizens.

Under the NATO Science for Peace (SfP) Programme, which was initially launched in 1997, the MIRVAX (Monitoring and Improving the Rivers in the Vardar/Axios Watershed) bilateral project was financed with EUR 320,000. The aim of the project was the Water Quality Tele-monitoring and Tele-controlled Network of the Vardar/Axios River, and the main objectives were designated to the following:

- Establishment and operation of the Vardar/Axios (VAX) Monitoring Network (VaxMN) complementing North Macedonia effort towards implementation of the Water Framework Directive (WFD).
- Identification of the chemical surface/ground water quality status and upgrading the capacities of the Central Laboratory in the North Macedonia Ministry of Environment and Physical Planning (MoEPP).
- Design and implementation of the SCADA (Supervisory Control and Data Acquisition) systems and the remote data processing system.
- Development of the Vardar Database (VaxDB) and Vardar Geographical Information System (VaxGIS) and calibration of the existing Vax water quality model MONERIS.
- Improving the Watershed Sustainability where initiatives and responsibility belong to the municipalities, regulators, citizens, and which is a set of social/policy tasks, by the establishment of: i) a volunteers' network, which will contribute to the development and implementation of the VAX River Basin Management Plan (RBMP), and ii) a sustainable scheme for scientific cooperation and technology transfer between North Macedonia and Greece.

2.3.3.1 The MIRVAX Project

MIRVAX initiative was conducted for having a positive impact on the humans' food and health while increasing the inhabitants' security sentiment and allowing the test of various rehabilitation methods. Moreover, it allowed the simulation of a terrorist action scenario of river toxic shock. With its capacity, the MIRVAX monitoring system was able to improve people security through the production of accurate water quality data and thereafter to justify further investments in the water treatment systems. With these capabilities, MIRVAX aimed at building up public confidence in the local water utilities, as well as building peace between the people in the Vardar/Axios watershed.

The MIRVAX system was based on the programmable logic controller (PLC) concept, *Figure 2-3*. The integrated automation system of the local monitoring station and the entire automated industrial type telemetry network had the capability and was also configured to conduct the analysis and measurements of Chemical Oxygen Demand, Chromium, Cadmium, Nickel, Chlorine and Manganese concentrations, Green Algae and Chlorophyll presence and concentration, Velocity measurement and Microbe population. Moreover, measurements and analyses of nitrate, nitrite, ammonium, phosphate, total organic carbon, turbidity, and toxicity were conducted through online analytical instruments. Additionally, the monitoring stations consisted of the following measuring instruments:

- Hydrostatic measuring device, for measuring the level of the river
- Dissolved Oxygen measuring device
- pH measuring device
- Conductivity measuring device
- Temperature measuring device

The specific project established a monitoring network of one fixed and eight mobile measurement sites, along with a monitoring plan for the measurement of the waters, mainly in North Macedonia. The monitoring system also included a supervisory control and data acquisition (SCADA) system, a database for storing the measured information, as well as a geographic information system (GIS) of the Vardar/Axios River basin where all the water-related spatial information, as well as the monitoring locations, were projected. Finally, the project involved the operational use of a flood model, a water quality model, and a watershed model that were triggered by data from the monitoring network.

a)

b)

Figure 2-3 a) Monitoring station, housed online real-time telecontrol spectrophotometers, b) River immersed sampling and measurement sensor cage

During the operational use of this telemetric monitoring system the main outputs regarding the water quality of the Vardar/Axios River are summarized as the followings:

- Vardar River had low water quality with respect to the relevant national standards;
- The physical characteristics - oxygen content and oxygen consumption- showed that there were conditions for good river water quality;
- Heavy metals (Fe, Pb, Cu, and Zn) were above the maximum allowed concentrations;

- The data in the bacteriological analysis were much higher than the limit standards;
- The low water discharges from April to September coincides with the river's lowest water quality;
- In July and August, the river water flow was occasionally lower than the environmental flow, and in these months the river water was full of communal wastewaters;
- The annual wastewater volume in the Vardar River was about 120 million m3 and only less than 10% received some type of treatment. Hence the river water quality was low, especially at the exits of the urban areas;
- From April to September, the Vardar River water quality was stable and classified as class III-IV;
- At the end of summer and beginning of autumn the Vardar River water quality was of stable class IV, or sometimes class V;
- From October to March, the Vardar River water quality was better, i.e. classified as class II-III, as a result of the higher river's water flow.
- There were no significant changes in the river water quality from the year 1995 until the end of the operational use of the monitoring network;

2.3.3.2 Additional bilateral cooperation and agreements

The two countries have developed intensive bilateral co-operation beyond the territorial co-operation framework. The two countries have signed a number of Memoranda of Understanding (MoU) in the field of environment. In addition, Greece has initiated the Hellenic Plan for the Economic Restructuring of the Balkans (HIPERB). Part of the obligations of the country within the OECD Development Co-operation Directorate, HIPERB is the commitment to provide development assistance to the Balkan countries, aiming to promote the political, economic, and social stability in these countries. During the period 2004–2011 North Macedonia received EUR 74.840.000, of which 79% was earmarked for large-scale infrastructure projects (IPA Cross-Border Programme , 2007). Among the developed projects, the following project was related to the management of the Vardar/Axios River. In particular, more than 2 million euros have been allocated for the purposes of the construction of the Wastewater treatment plan of Gevgelija and the building of a sewage system and a system for water supply in the municipality of Gevgelija.

2.3.4 EU environmental legislation as a framework for cooperation

The differences in the national legislative environmental frameworks of riparian countries are obstacles that usually set problems on the management of the waters at basin scales. In Greece, for example, three of the riparian countries which share a water body with Greece, namely Turkey, North Macedonia, and Albania, are not members of the EU, and hence there is no common legislative framework for cooperation. However, all these countries have started or are about to start the accession process to the EU, i.e. complying with their national legislation with the WFD. This process involves compliance with the accession criteria, i.e. political, economic, and administrative, and institutional capacity criteria, including adoption and implementation of the acquis, i.e. what is already adopted by the EU (Kolokyhta & Skoulikaris, 2019).

Focusing on the Western Balkans, although the several challenges that the under-accession states need to address, the EU accession process is the main political driver, providing opportunities for improvements in the environmental sector (T.M.R., 2019). The efforts that North Macedonia makes to adopt the WFD as the legal and operational framework for its water resources management has been recognized by the EU that provides financial and technical support (e.g. the EuropeAid (2011/S 205-332720) project: Technical Assistance for Strengthening the Institutional Capacities for Approximation and Implementation of Environmental Legislation in the Area of Water Management) (Kolokyhta & Skoulikaris, 2019).

The Stabilization and Association Agreement (SAA) between North Macedonia and the EU entered into force in April 2004. In 2009, the Commission proposed the passage to the second stage of the SAA. In light of the progress achieved in previous years, in 2018, the European Council agreed on the opening of accession negotiations, which started in June 2019. All these years, the Commission reported about the achieved progress of North Macedonia to complying its national legislation with the EU legislation. Focusing on the environment and particularly on water resources management, the progress that was achieved during the last 10 years is remarkable. The 2010 EC Progress Report on North Macedonia (EC, 2010), for example, mentioned "*Little progress can be reported in the area of water quality. Some implementing legislation was adopted. The implementation of the Water Law was postponed by one year. The administrative capacity to deal with integrated water management is largely insufficient and a clear division of responsibilities in this field still needs to be established. Very little progress is being made in addressing the important gaps in the water monitoring system. No progress was made in applying the user/polluter-pays principles*". On the other hand, the 2019 EC Progress Report on North Macedonia (EC, 2019) clearly mentioned that the aforementioned shortcomings were properly advanced and moreover states "*Regarding waste management, further progress was made in aligning the legal framework with the EU rules. The new Law on Waste and the national waste prevention plan has not been adopted, but the new 2018-2024 national waste management plan has been prepared. Several laws on special waste streams are pending adoption. The regional waste management plan for the Polog region is underway. The integrated waste management* *system is still delayed as setting up the regional structures took longer than expected."*

The same report (EC, 2019) refers to the progress made on climate change issues as "*The alignment of the legal framework with the acquis is still at an early stage. The country has started developing a comprehensive strategy on climate action, consistent with the EU 2030 framework. It should also pursue efforts to implement the Paris Agreement, which North Macedonia ratified in November 2017. In 2018 the country submitted its second Biennial Update Report on climate change to the United Nations Framework Convention on Climate Change and currently, the 4th National Communication and 3rd Biannual Update Report to the UNFCCC are in preparation*."

The integration of EU environmental legislation in North Macedonia's national legislation has proved an important asset for coping with issues that are related the water resources. North Macedonia is about to finalize its accession process, and hence the common legislative framework on water resources management between Greece and North Macedonia will facilitate the coordinated cooperation for the protection of the water resources and the management of the transboundary water bodies.

The progress that has been made in the quality of the Vardar water during the last years is also mentioned in the literature. As mentioned in Section 2.3.3.2 the pollution coming from the upstream part of the Vardar/Axios basin, due to lack of WWTPs and illegal dumpsites for solid waste, has long been an issue of conflict between North Macedonia and Greece. However, Skoulikaris and Zafirakou (Skoulikaris & Zafirakou, 2019) clearly depict that the water quality of the river water bodies close to the borders presents a different picture. In particular, the waters entering Greece have a good quality status and the degradation of the water quality coincides with the irrigated agriculture that takes place in the Greek plains of the basin. The main reason behind the improvement of the upstream inflows' quality is the operation of a WWTP in the border city of Gevgelija in North Macedonia, while similar projects are under construction in the country's municipalities.

2.4 Perspectives of cooperation

The Prespa agreement of the 12th June 2018 is the new cornerstone for the cooperation between the two countries. The agreement, whose full name is "Final Agreement for the settlement of the differences as described in the United Nations Security Council Resolutions 817 (1993) and 845 (1993), the termination of the Interim Accord of 1995, and the establishment of a Strategic Partnership between the Parties" was ratified by the two countries under the United Nations' auspices and concluded on i) the former Yugoslav Republic of Macedonia (fYROM) is renamed to the Republic of North Macedonia with the new name being used for all purposes (erga omnes), and ii) the citizenship of North Macedonia will be called Macedonian/citizen of the Republic of North Macedonia and the Macedonian language is recognized by the United Nations.

Global water-related challenges, such as climate change mitigation and adaptation, as well as regional challenges, such as pollution of water bodies, can be perceived as common objectives that foster cooperation for providing solutions at a river basin scale. EU research and development funds together with international financial resources, such as the joint UNDP-UNEP NAP Global Support Programme, could provide the means for joint activities and water-related development projects.

2.4.1 Climate change adaptation

Climate change is a universal challenge that needs to be addressed through global policies and cooperation initiatives. The impacts of climate change on water resources could be comprised of increases in temperature, shifts in precipitation patterns and snow cover, and a likely intensification of the frequency of extreme events (floods and droughts) (IPCC , 2018). Based on an analysis conducted by the Environment and Security Initiative (UNEP and Zoï Environment Network, 2012), the Balkan region is getting warmer and it is projected to follow the global trend regarding the expected increase in global temperatures. Similarly, the region is projected to receive less precipitation, and to experience further discharge decreases, although precipitation patterns will continue to vary according to terrain, elevation, and proximity to the sea.

At the Vardar/Axios basin scale, Popovska (Popovska, 2002) based on the Vardar River discharges for the period 1951-2000, conducted an analysis of the past and future trends of the river discharges. In particular, the average flow Vardar River at Skopje for the periods 1971-1980, 1981-1990, and 1991-2000 was 64.56 m^3/s, 53.61 m^3/s, and 46.0 m^3/s respectively, i.e. presenting every ten years an average flow reduction of 14%-17%. Moreover, the maximum flows in river Vardar within the period 1961-2000 have reduced by 79%, i.e. from 983.0 m^3/s during the period 1971-1980, to 404.0 m^3/s and to 226.0 m^3/s for the periods 1981-1990 and 1991-2000 respectively. The author concluded that if the presented trends continue in the future, the 2050 average flows will be reduced to 20.0 m^3/s, and the maximum flow to only 85.0 m^3/s. Monevska (Monevska, 2011) used the outputs of four GCMs (CSIRO/Mk2, HadCM3, ECHAM4/OPYC3, NCAR-PCM) scaled to six emission scenarios (SRES A1T, A1Fl, A1B, A2, B1, and B2) to identify the projected changes of average daily air temperature (°C) and precipitation (%) in North Macedonia with regard to the period 1961–1990. The author demonstrated that the average temperature will be increased by 1.9°C, 2.9°C, and 3.8°C in the years 2050, 2075, and 2100 respectively, while the precipitation will be decreased by 5%, 8%, and 13% respectively for the aforementioned time periods. Thus, it is likely that the water bodies within the catchment area of Vardar River will meet serious flow decreases in the next century. This would lead to raise in transboundary water management issues.

In the Greek part of the basin, apart from the foreseen reduced inflows from North Macedonia due to climate change, which will have significant impacts on the irrigated agriculture, the Axios basin is subjected to problems related to sea-level rise. According to the 6th National Communication to United Nations Framework Convention on Climate Change (UNFCCC) (Hellenic Ministry of Environment, Energy and Climate Change, 2014), the total coastline length presenting medium to high vulnerability to sea-level rise amounts to 3,360 km or 21% of Greece's total shoreline, with Axios River coastal area to be highlighted as a high vulnerable region.

North Macedonia also reports to the UNFCCC, and has developed three National Communications to the UNFCCC, the First Biennial Update Report, and the 2015 Intended Nationally Determined Contributions (INDC). As part of North Macedonia's Third National Communication (North Macedonia Ministry of Environment and physical planning, 2014)), analysis of impacts, vulnerability, and adaptive capacity was undertaken for the following sectors: agriculture and livestock, biodiversity, forestry, human health, tourism, cultural heritage, water resources, and socio-economic development. A special focus was given on the Southeast Region, which had been identified as being especially vulnerable to climate change. Moreover, North Macedonia requested support for the development of its National Adaptation Plan (NAP) process and was one of the first countries requesting the Green Climate Fund (GCF) financing for that purpose. Thus, with the support from the joint UNDP-UNEP NAP Global Support Programme (NAP-GSP), a preliminary mission was undertaken in March 2017 to identify, in consultation with stakeholders, the country's needs regarding the NAP process.

The EU Strategy on Adaptation to Climate Change was launched in 2013 in accordance with the context of the UNFCCC, where the EU is a fundamental member. The adaptation strategy encouraged all EU member states to adopt comprehensive adaptation strategies (EU, 2013). The objectives of the strategy focus on the i) promotion of action by the member states, such as the formulation of National Adaptation Strategies (NAS), a tool that is also recommended at the global level by the UNFCC, ii) promotion of better-informed decision-making, an issue that will be addressed with funding from EU's program frameworks for research and innovation, and iii) promotion of adaptation in key vulnerable sectors, such as the water resources and agriculture. Towards this direction, Greece formulated in 2016 its National Adaptation Strategy (NAS) to Climate Change which sets out the general objectives, principles, and implementation tools of an effective and growth-oriented adaptation strategy (MEEN, 2016). Together with the NAS (or NAP), has started formulating the regional adaptation action plans where the Regional Authorities are obliged to (i) perform a detailed assessment of potential climate change impacts for short, mid-term, and long-term time horizons, (ii) identify and map relevant regional climate-related risks, vulnerabilities, and hotspots, (iii) prioritize adaptation action based on their cost-effectiveness and benefits, (iv) identify synergies with other policies and regional plans, such as land-use plans, water basin management, and flood risk management plans, and to (v) integrate, as needed, priority measures into regional planning (Kolokytha & Skoulikaris, 2020). Based on the aforementioned, climate change adaptation could be considered as a consolidated cooperation framework for the development of a regional climate change adaptation strategy focused on the Vardar/Axios river basin. The experience of Greece together with the willingness of North Macedonia to climate change actions is a unique opportunity for common programs/projects at a basin scale.

2.4.2 EU funded cooperation opportunities

As mentioned before, the INTERREG IPA Cross Border Cooperation Programme "Greece – the Republic of North Macedonia 2014-2020" is the most recent INTERREG programme promoting opportunities for cooperation, good neighborly relations, and socio-economic development to the two countries. The 2nd Call for Proposals, which was launched in early 2020 aimed for project proposals with a synergetic outlook and strong institutional partnership and had three specific objectives (SO), with the SO 2.4 Natural Disasters to focus on water-related disasters. Six proposals are submitted within the specific objective to be funded with €1.4 million, while until the time this chapter was written the evaluation of the submitted proposal was in progress.

In any case, the INTERREG programme is a well-established framework that has a non-stop flow of funding opportunities related to the environment. The programme continues to be one of the instruments and accelerators for the implementation of cohesion policy by promoting a large-scale exchange and transfer of experiences, peer learning, and benchmarking across Europe. The next edition of the INTERREG Europe programme 2021-2027 is still under development and is planned to be finalized in early 2021. However, the 1st draft version of this programme, which is available online[1], demonstrates the following three major pillars that will be funded:

1. Climate change and environmental degradation: The European Green Deal provides a roadmap for making the EU's economy sustainable with action to boost the efficient use of resources by moving to a clean, circular economy, and to restore biodiversity and cut pollution. The EU is committed to becoming

1 Europe cooperation programme (accessed 23.10.2020)

climate-neutral by 2050. Thus, climate neutrality by investing in innovative technological solutions, empowering citizens, and aligning action in key areas such as research is one of the next call main objectives.

2. The 2030 Agenda for Sustainable Development. This is also a major objective for the EU and emphasis will be given to implement and progress on the achievement of the 17 Sustainable Development Goals (SDGs), considering national realities, capacities, and levels of development and specific challenges. SDG 6 focuses on Clean water and sanitation with its specific target 6.5 to related to transboundary water resources management. Hence, innovative concepts and approaches on the Vardar/Axios basin management could receive the appropriate funding to be implemented.

3. The implementation of all EU strategies. The aim of this pillar is to strengthen territorial cohesion in Europe. It will provide strategic orientations for spatial planning and for strengthening the territorial dimension of all relevant policies at all governance levels.

An additional option for funding opportunities is derived by the Horizon Europe, an ambitious €100 billion research and innovation programme that will succeed Horizon 2020 programme, and it will be launched in 2021. Horizon Europe will incorporate five research and innovation missions, with "Adaptation to climate change including societal transformation" and "Healthy oceans, seas, coastal and inland waters" to be two of the proposed missions. Regarding the adaptation to climate change, the objectives are more or less defined in the report entitled "A Climate Resilient Europe - Prepare Europe for climate disruptions and accelerate the transformation to a climate resilient and just Europe by 2030" (EC, 2020). The objective, of "*building deep resilience by scaling up actionable solutions triggering societal transformations through 100 deep demonstrations of resilience across a number of European communities and regions, with emphasis on cross-border cooperation and cohesion*" is a research area that the transboundary region of the Vardar/Axios basin perfectly matches for implementing cooperative climate resilience actions. At the same time, the objectives of the thematic area of healthy oceans, seas, coastal and inland waters are considered a powerful tool to raise awareness of their importance among citizens and help develop solutions on a range of issues, such as systemic solutions for the prevention, reduction, mitigation, and removal of marine pollution. In that case, actions related to the amelioration of the water quality of the Vardar/Axios that is finally discharged into the Aegean Sea could be proposed as a cooperation initiative between the two countries.

3

The Vardar/Axios as a case study for joint cooperation in the wastewater treatment: challenges, interests, and benefits for both sides

3 The Vardar/Axios as a case study for joint cooperation in the wastewater treatment: challenges, interests, and benefits for both sides

by Antigoni Zafirakou and Iljco Jovanovski

All wealth comes from Nature. Without it, there wouldn't be any economics…

Margaret Atwood

Every community produces three kinds of wastes: solid, liquid, and air emissions. Wastewater is one part of the liquid waste that is produced by all human activities; it is essentially the water that is supplied to a community and is returned into the environment, after being used. In the urban cycle of water, as shown in Figure 3-1, the urban environment uses the water provided by nature and returns it to the natural environment after treating it and/or reusing it effectively. This is called sustainable urban wastewater management, as it will be analyzed in the next paragraphs.

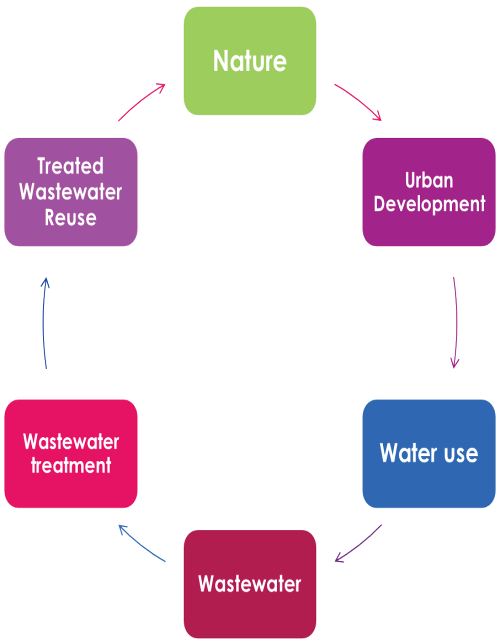


Figure 3-1 Urban cycle water

Due to urban development, particularly in developing countries, water resources are under pressure from continuing population growth, urbanization, rapid industrialization, expanding, and intensifying food production. Statistical projections show that urban populations may nearly double from the current 3.4 billion to 6.4 billion by 2050[2].

According to data collected from different countries of the world, the average water use per person varies from a little bit above 0 L/d, in Mozambique, Africa, to more than 550 L/d in the United States of America (Fig. 2). Greece is very rapidly approaching 250 L/d/cap.

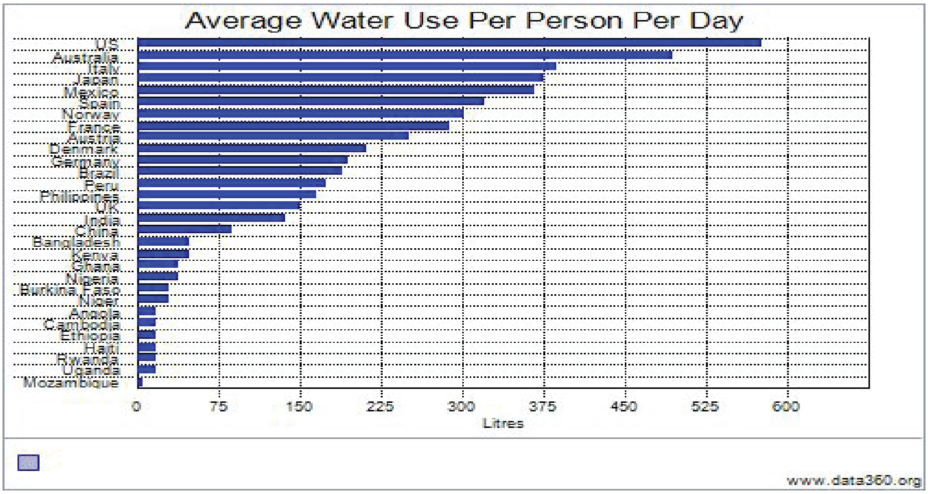


Figure 3-2 Average water use per person per day in City networks (Zafirakou, 2017)

New terms have been introduced, to better describe the situation. The water footprint is a measure of humanity's appropriation of freshwater in volumes of water consumed and/or polluted. "The interest in the water footprint is rooted in the recognition that human impacts on freshwater systems can ultimately be linked to human consumption and that issues like water shortages and pollution can be better understood and addressed by considering production and supply chains as a whole," says Professor Arjen Y. Hoekstra, creator of the water footprint concept. An interactive map, created by Michiel van Heek (Water Footprint Network) & Arjen Hoekstra (University of Twente) provides all the related information. [3]

In this map, attention has been given to the internal versus the external water. For instance, for Greece internal is 54% and the remaining 46% is from external

2 greenfacts.org - Wastewater management (accessed 23.10.2020)
3 waterfootprint.org - National water footprint explorer (accessed 23.10.2020)

sources. According to US Infrastructure[4] the water footprint of a country is defined as "the volume of water needed for the production of goods and services consumed by the inhabitants of the country", which is expressed in detail in Figure 3-3. More than 2.8 billion people in 48 countries will face water stress or scarcity conditions by 2025, and close to 7 billion by 2050, is the estimation according to the global water footprint and WWF. The daily drinking water requirement per person is 2–4 L/d, but it takes 2000-5000 L of water to produce one person's daily food[5].

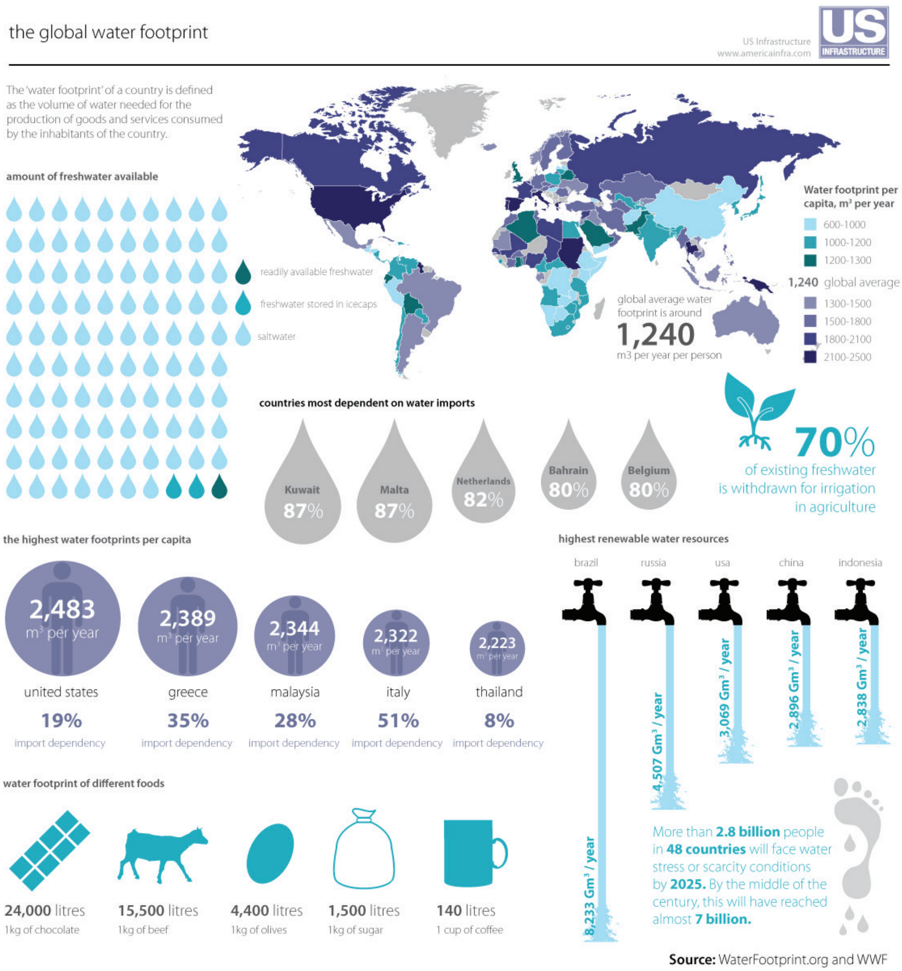


Figure 3-3 The global water footprint

4 www.americainfra.com
5 www.greenfacts.org – Wastewater management

Water stress, according to the European Environmental Agency, occurs when the demand for water exceeds the available amount during a certain period, or when poor water quality restricts its use [6]. Water stress causes deterioration of freshwater resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.). According to Figure 3-4, 3.2 billion people living in river basins will suffer from severe water stress by 2025, and 4.9 billion by 2050, while 1.6 billion were estimated in 2007 to be living in river basins with water scarcity.

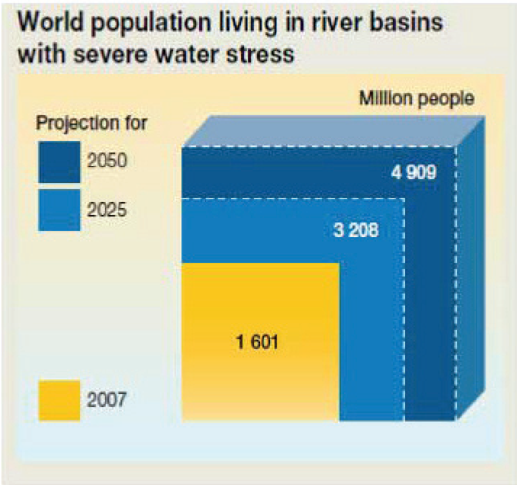


Figure 3-4 Projection of world population in river basins with severe water stress[7]

It is well acknowledged that the world's natural water resources will not augment, but the amount of wastewater produced is continuously increasing, therefore the infrastructure and management systems must meet the requirements for this increasing volume. Globally, 2 million tons of sewage (industrial and agricultural waste) is discharged - not counting the unregulated or illegal discharge of contaminated water. This wastewater contaminates freshwater and coastal ecosystems, threatening food security, access to safe drinking and bathing water, and being a major health and environmental management challenge. At least 1.8 million children under 5 years die every year from water-related diseases. Diarrheal diseases make up over 4% of the global disease burden, 90% of which is linked to environmental pollution, a lack of access to safe drinking water and sanitation. Over 50% of the world's hospital beds are occupied by people suffering from water-related diseases. This represents a global threat to human health and wellbeing,

6 www.eea.europa.eu – Water stress definitions
7 Source: https://www.greenfacts.org/en/wastewater-management/l-2/index.htm

with both immediate and long-term consequences. Improved sanitation and wastewater management are of profound importance.

According to Dr. Tchobanoglous (Tchobanoglous & Angelakis, 1996) (invited lecture at the Aristotle University of Thessaloniki, 2017), the new challenges are the outcomes that were not anticipated, foreseen, or predicted by purposeful action, due to the impact of the law of unintended consequences on wastewater management. Namely, these are:

» Population demographics
» Water quality distribution
» Climate change

Any reported change in those sections will disturb the equilibrium in the water management and the projected lifetime of a wastewater treatment facility. The water quality distribution is extensively analyzed above.

With respect to the population demographics, Greece lately is demonstrating generally stability or even slight decrease between the years 2001 and 2011, as depicted in Table 3-1, probably due to the economic crisis, which forced its people to migrate.

Table 3-1 Greece's population demographics (2001-2011) with a focus on northern districts

District	**2001**	**2011**
Eastern Macedonia & Thrace	607.162	608.182
Central Macedonia	1.874.597	1.880.058
(Thessaloniki)	(1.057.825)	(1.012.013)
Western Macedonia	294.317	283.689
Greece	**10.934.097**	**10.815.197**

With respect to climate change, the pace of global sea-level rise nearly doubled from 1.7 mm/yr throughout most of the 20th century, to 3.1 mm/yr since 1993. By 2040, 60-70 % of the world's population will live near a coastal region. Therefore, withdrawing water from inland areas, transporting it to urban population centers, treating it, using it once, and discharging it to the coastal waters is unsustainable. This is why WWTPs around the world are moving towards advanced treatment so that their effluents comply with the drinking water criteria and can satisfy the water demands of deserted areas or hydrologically poor. A few countries like Singapore, Australia and Namibia, and states such as California, Virginia, and New Mexico are already drinking recycled water, demonstrating that purified wastewater can be safe and clean, and help ease water shortages. More about advanced treatment technology will be portrayed at the end of the chapter.

On the other hand, the intensity and frequency of heavy rainfalls are affecting the operation of WWTPs, as depicted in the following charts. The sludge produced and accumulated in the tanks is proportionally increased.

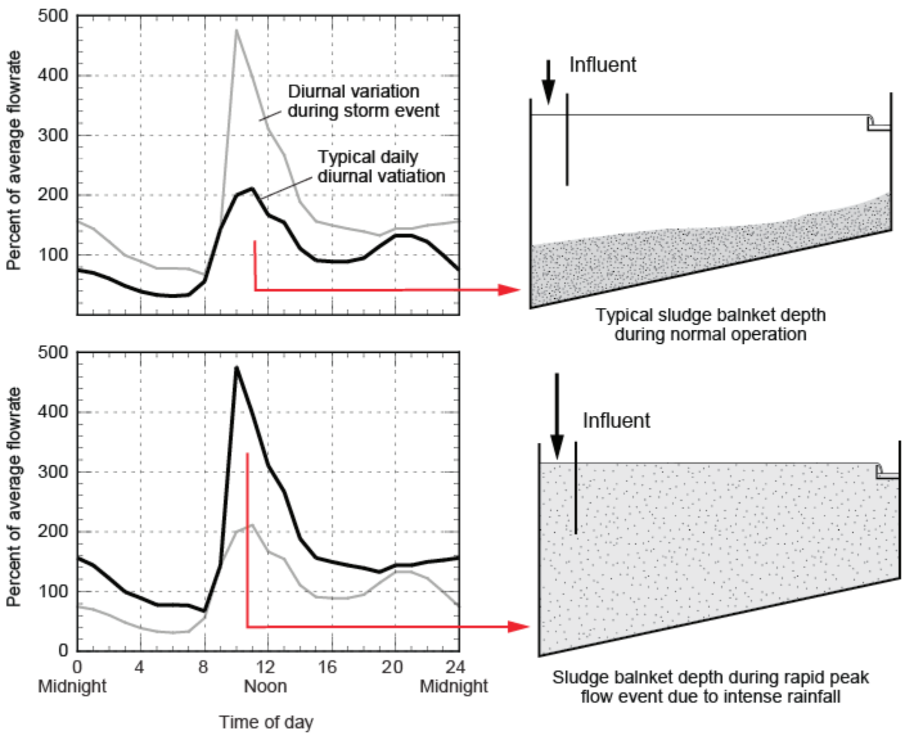


Figure 3-5 The effect of climate change on the operation of a WWTP[8]

3.1 Wastewater management

Water supply and sewerage systems have been built for more than 2,000 years, dating back to the Roman Empire. However, the study of wastewater treatment is a relatively new scientific discipline as it began to develop just over 100 years ago. The intensification of the problem of wastewater treatment occurs in the 18th century

8 Source: Tchobanoglous, 2017

when due to unhygienic conditions various epidemics appeared and spread. In this regard, sewerage systems that take wastewater out of populated areas to natural watercourses were being built, but as a consequence of this, the problem of eutrophication of watercourses arose.

Due to the increasing pollution of watercourses with wastewater, which exceeds the ability for their self-treatment, at the beginning of the last century criteria were set for intentional wastewater treatment.

The simple drainage and sinking of wastewater to land areas quickly came into force due to the need for large areas. Opportunities were sought to increase the load per unit area, and thus reduce the need for adequate land area. Some improvement was achieved through previous mechanical treatment of wastewater, but even that soon proved to be insufficient.

Wastewater engineering is the brunch of environmental engineering in which the basic principles of science and engineering are applied to solving the issues associated with the treatment and reuse of wastewater (Tchobanoglus, et al., 2003).

The term wastewater management refers to the holistic management of wastewater towards the benefit of the environment and the protection of public health. It consists of both the collection of wastewaters and its treatment as well as the reuse of treated wastewater and its produced sludge (Figure 3-6).

Figure 3-6 Stages of urban wastewater management

In addition to these stages, wastewater management also includes the selection of the location of the WWTP, the Environmental Impact Study, the design, construction, and operation of the WWTP, and the monitoring of the effluents (Figure 3-7).

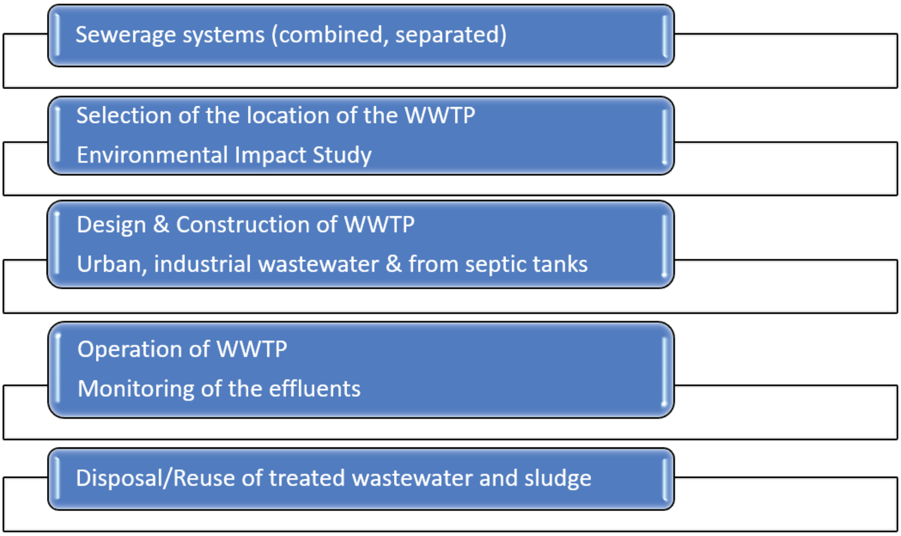


Figure 3-7 Sustainable WWT design and management

The main sources of wastewater are urban and industrial wastewater and stormwater. Urban, or municipal or domestic, wastewater is collected via sewerage pipes from households, municipal buildings, and parks, schools, hospitals, etc. When there is no infrastructure of pipelines (sewerage system), then wastewater is stored in the sewer or septic tanks and transferred to a treatment facility with tank-vehicles. Rainwater, or stormwater or snowmelt, may be managed as surface runoff in open channels or collected in partly full conduits. Industrial wastewater is conveyed into the urban sewerage system or directly to the treatment plant, most frequently, after pre-treatment. Wastewater treatment is a series of operations and processes (mechanical, physical, chemical) that wastewater must undergo in order to eliminate various contaminants, to protect public health and the natural bodies of water (groundwater, rivers, lakes, oceans), where it ends its course.

3.1.1 World global water quality crisis and the need for wastewater treatment plants

Usually, the identification of the issue for the need of WWTP is done through the following questions:

» Why is it important to build a WWTP?

Wastewater is generated from households, human and animal waste, industry, partly from stormwater and groundwater that infiltrates into the soil. Wastewater carries components (contaminants) that must be removed or reduced accordingly before the effluent is discharged. According to the existing legislation, the collected municipal wastewater should be treated appropriately before the discharge into the recipient, discharge to the ground, or reuse. When designing the technological process, the following questions are asked:

- What level of treatment should be established to ensure an adequate level of environmental protection?
- What type of processes and devices should be used to achieve this goal?

To answer these questions, an analysis of local conditions and needs, application of scientific knowledge and engineering practices will be made, taking into account the current national regulations and legislation. An overview of today's best techniques and technologies for wastewater treatment will be also made with an emphasis on the process of biological treatment with activated sludge.

Water supply and sewerage systems are one of the infrastructural pillars of modern society. It is a complete system that contains the treatment of drinking water and distribution to users, its utilization, collection of used wastewaters, its transport, treatment and return to nature.

Water supply and sewerage systems have been built for more than 2,000 years, dating back to the Roman Empire. However, the study of wastewater treatment is a relatively new scientific discipline as it began to develop just over 100 years ago. The intensification of the problem of wastewater treatment occurs in the 18th century when due to unhygienic conditions various epidemics appeared and spread. In this regard, sewerage systems that take wastewater out of populated areas to natural watercourses were being built, but as a consequence of this, the problem of eutrophication of watercourses arose.

Due to the increasing pollution of watercourses with wastewater, which exceeds the ability for their self-treatment, at the beginning of the last century criteria were set for intentional wastewater treatment.

The simple drainage and sinking of wastewater to land areas quickly came into force due to the need for large areas. Opportunities were sought to increase the load per unit area, and thus reduce the need for adequate land area. Some improvement was achieved through previous mechanical treatment of wastewater, but even that soon proved to be insufficient.

3.1.2 Wastewater collection

Wastewater collection can be achieved either by collecting both urban and stormwater in one-pipe system (combined sewerage), or by collecting only the urban sewage in semi-filled pipelines and the stormwater in separate also partly-filled pipelines (separate sewerage), as shown in Figure 3-8.

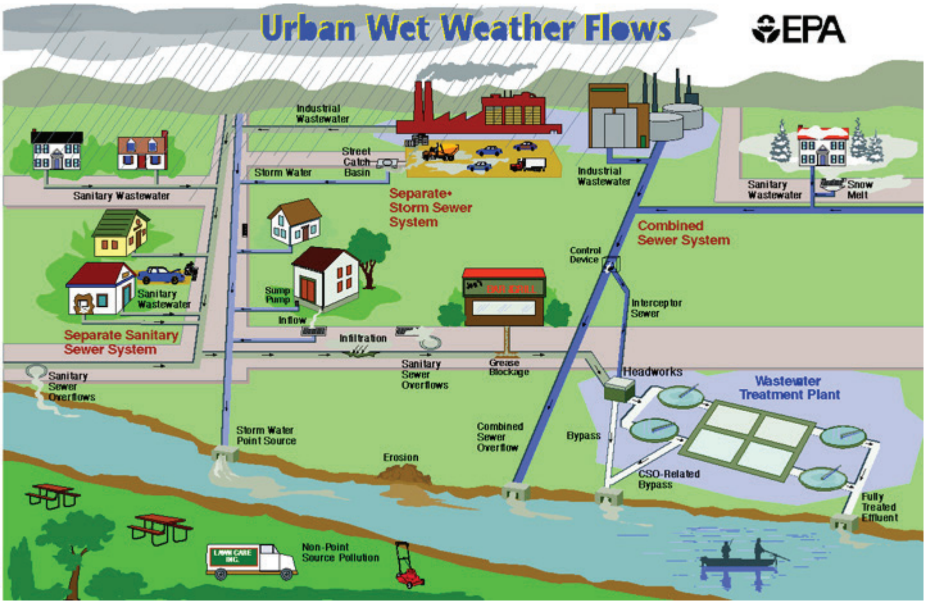


Figure 3-8 Separate and combined sewer systems (EPA)

The first sewerage systems were collecting both wastewater and stormwater in one pipeline, but were releasing one amount of the stormwater to the closest waterbody, as overflow, in periods of heavy rain (CSO), whereas the remaining is directed to a Wastewater Treatment Plant (WWTP). Modern sewerage systems are constructed with separate pipes for the urban (or sanitary) and industrial wastewater, which are directed to a Wastewater Treatment Plant (WWTP), whereas the stormwater may fall into the closest water body, untreated, but free of organic matter, only carrying the contaminants of surface runoff.

3.1.3 Wastewater treatment

After the sewage is collected, it needs to be cleaned or treated. The question posed is “what levels of treatment must be achieved to ensure the protection of the environment and public health?”. It depends on several parameters. The national regulations, the sensitivity level of the water body, and whether it contains or is part of a protected area, such as Natura 2000 and Ramsar convention, whether the water body is used as a source of potable/drinkable water. Depending on these parameters, there are different levels of sensitivity and different levels of treatment. The basic stages of treatment are given in the following graphical representation (Figure 3-9), which coincide with Metcalf & Eddy (Tchobanoglus, et al., 2003).

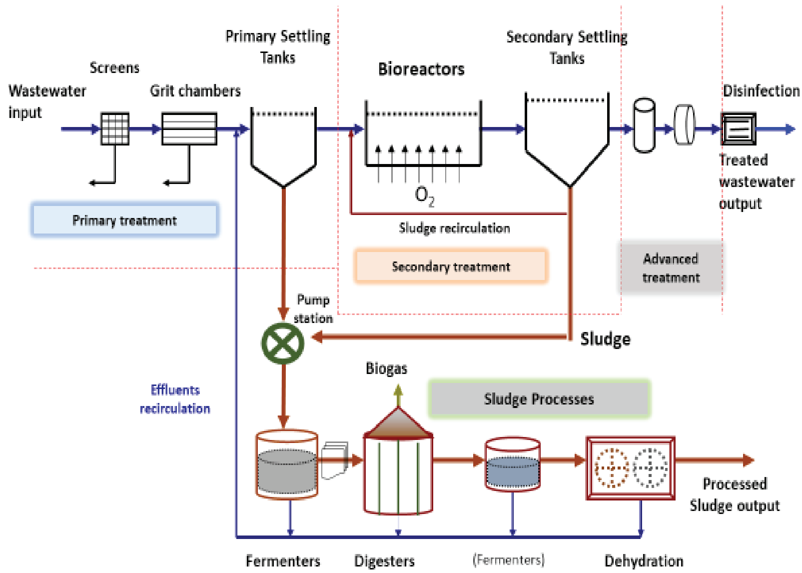


Figure 3-9 Typical flow chart of a wastewater treatment plant

Primary treatment: In the literature, it is often distinguished into preliminary and primary treatment. In the preliminary stage, wastewater constituents are removed, to protect the units of the facility from operational problems. The primary stage is directed towards the removal of a portion of suspended solids and organic matter. The primary treatment may be enhanced with chemicals to achieve a better level of treatment.

Secondary or biological treatment: In this stage, the removal of biodegradable organic matter (in solution or suspension) and the removal of suspended solids is accomplished. Depending on the sensitivity of the water body recipient of the effluents the secondary stage may also include the removal of nutrients (nitrogen and/or phosphorus).

Tertiary treatment: It consists of the removal of residual suspended solids, usually by granular medium filtration or micro screens.

Advanced treatment: This stage is required especially when treated wastewater is planned to be reused. It consists of the removal of dissolved and suspended materials remaining after normal biological treatment.

Disinfection: It is the final stage of treatment typically after the secondary stage.

Wastewater treatment focuses primarily on the removal of biological oxygen demand (BOD), total suspended solids (TSS), and pathogenic microorganisms. Since 1980s the emphasis has shifted to the removal of constituents that may cause long-term health effects to humans and have severe environmental impacts. Consequently, the required degree of treatment has increased significantly. In the following Table 3-2, some typical values are given on the quality characteristics of urban wastewater collected from a sewerage pipeline system, as the daily quantity per capita, or as a concentration (in mg/L).

Table 3-2 Wastewater quality characteristics from urban sewerage

Parameter	Flow per capita g/capita/day	Concentration mg/L
TSS	20	130
BOD_5	60	400
Total- P	2 – 3	14 – 20
$N\text{-}NH_4$	6	40
Sediments	45	300

The corresponding quality characteristics of 1 m^3/capita/yr of urban wastewater collected from septic tanks, with 98.5% water and 70% organic matter, are given in Table 3-3.

Table 3-3 Wastewater quality characteristics from septic tanks

Parameter	Concentration mg/L
BOD_5	5000 mg/L
BOD_5 after sedimentation	2500 mg/L
COD	15000 mg/L
COD after sedimentation	6000 mg/L
Total N	550 mg/L
NH_4^+ - N	300 mg/L
Total P	150 mg/L
Organic acids	750 mg/L
pH	7

Table 3-4 The effect of various treatment processes to untreated wastewater (mg/L)

Parameters	Untreated wastewater	Primary treatment	Biological treatment without nitrification	Biological treatment with nitrification/ denitrification	Biolological treatment with nitrification/ denitrification and P removal
TSS	~400	180	40	20	10
BOD_5	400	250	20 – 40	15	15
P_{tot}	15	10 – 15	8 – 10	8 – 10	2
$N\text{-}NH_4$	40	35	30 - 35	1	1

Up until the late 1980s, conventional secondary treatment was the most common method for the removal of BOD and TSS. Because of nutrient enrichment that led to eutrophication and water quality degradation, in sensitive water bodies, biological treatment combined with nitrification/denitrification processes and/or phosphorus removal have been introduced and are widely used. The effect of various treatment methods on specific parameters of quality characteristics of wastewater is depicted in Table 3-4. The design of a wastewater treatment facility is taking into consideration various parameters, and therefore it may vary from case to case. For instance, the removal of phosphorus may occur at different stages. In Kavala's WWTP (northern Greece), phosphorus removal is taking place before the aeration of wastewater (Figure 3-10), which involves a denitrification and nitrification process.

Figure 3-10 Phosphorus removal before the biological treatment in Kavala's WWTP

Wastewater treatment plants basically imitate nature, by removing pollutants at a much faster pace. Nature has the ability to self-clean the water that runs through, at a very slow pace. Technology improves it by accelerating this pace.

However, in small communities' WWTPs one option is to use artificial or constructed wetlands and aerated ponds, as shown in Figure 3-11 and Figure 3-12, if areas are available.

Figure 3-11 Constructed wetland

Figure 3-12 Aeriated pond

One important stage of the treatment is disinfection, which is the last before the effluents flow in the environment. The most common disinfection method is chlorination, which is effective and less costly than others, as the following table shows, but not considered as environmentally friendly. Other methods, such as ultra-violet (UV) and membranes, are more friendly to the environment, and efficient at the same time, but more costly.

Table 3-5 Comparative analysis of different disinfection methods

Disinfection methods	Efficiency	Operational experience	Environmentally friendly technology	Cost € / m³
UV	+	++	+	0,05 – 0,10
Chlorination	++	++	-	0,08 – 0,12
O_3	+	+	-	0,10 – 0,35
Membranes	++	-	++	0,40 – 1,60

3.1.4 Wastewater disposal

The sanitary requirements for wastewater effluents are:

» The effluent wastewater available to the recipient water bodies must be extremely diluted (1: 10^6 - 1: 10^7)

» For drinking water, no coliforms are allowed in a sample of 100 ml of water
» For bathing waters, fish farms, and shellfish in different countries, similar standards apply

European Directives & Greek implemented Laws on Wastewater

76/464/EEC (L123 of 18/5/1976)
"Concerning pollution caused by certain dangerous substances discharged into the aquatic environment of the Community"

86/280/EEC (L181 of 4/7/1986)
"On limit values and quality objectives for discharges of certain dangerous substances included in List I of the Annex to the Directive 76/464/EEC"

JMD 55648/2210/1991 (GG 323B/1991)
"Measures and limitations for the protection of the aquatic environment and in particular the establishment of limit values and hazardous substances in waste water"

Figure 3-13 European Directives & Greek Implemented Laws on Wastewater (EEC = European Economic Community, JMD = Joint Ministerial Decision, GG = Government Gazette)

91/271/EEC (L181 of 4/7/1986)
"Concerning the collection, treatment and disposal of urban and industrial wastewater"

JMD - 5673/400/97 (GG 192 B)
"Measures and conditions for urban waste water treatment, and for industrial wastewater which can be inserted into urban sewerage networks after pretreatment"

Figure 3-14 European Directives & Greek Implemented Laws on Wastewater (EEC = European Economic Community, JMD = Joint Ministerial Decision, GG = Government Gazette)

These Directives (Figure 3-13 and Figure 3-14) determine directly or indirectly

- The equivalent population estimates
- The timetable for implementing the required projects depending on the population served or the population equivalent
- The sewerage systems and wastewater treatment plants (WWTP)
- The required level of treatment to be provided by WWTP
- The disposal of industrial waste in sewage systems
- The methods of measuring organic loads depending on the type of waste
- The sensitivity of the water bodies
- The authorization of discharges from sewage treatment plants

The United Nations Conference on Sustainable Development took place in Rio de Janeiro, Brazil on 20-22 June 2012. It resulted in a focused political outcome document which contains clear and practical measures for implementing sustainable development. In Rio, the 193 Member States decided to launch a process to develop a set of Sustainable Development Goals (SDGs), which will build upon the Millennium Development Goals and converge with the post-2015 development agenda. The Conference also adopted ground-breaking guidelines on green economy policies. Governments also decided to establish an intergovernmental process under the General Assembly to prepare options on a strategy for sustainable development financing. They also agreed to establish a high-level political forum for sustainable development. The Conference also took forward-looking decisions on a number of thematic areas, including energy, food security, oceans, cities.[9]

3.1.5 Process of preparation of wastewater collection and treatment infrastructure project

3.1.5.1 Background information

The WWTPs tend to have relatively high investment and operational costs, with extremely energy-demanding processes. They are usually operated by the Public Utility Companies, which are facing insufficient budgets for the operation and maintenance of such plants. The selection of the most appropriate treatment technology is of the highest importance during the planning of this kind of long-term investment.

The WWTP processes cannot be customized because every plant has to solve different kinds of local conditions, such as flow, level of pollution, effluent quality, available technology, level of expertise of the operators, and many other local issues.

9 www.sustainabledevelopment.un.org/rio20.html

During the selection process of the appropriate technology, all local conditions have to be taken into account.

This chapter presents the methodology, as a tool that will guide the planner or designer to select the most appropriate treatment technology for any case having in mind the Best Available Techniques that exist today. The methodology follows the algorithm with logical steps in the process of planning and selection.

If multiple technologies qualify for a certain case, comparative techno-economic analysis with Net Present Value (NPV) is calculated in order to justify which of them would be the economically most advantageous option. And finally, multi-criteria analysis is applied for their evaluation and ranking.

3.1.5.2 Methodology for selection of the most appropriate wastewater treatment technology

The usual questions that municipal planners, the design and process engineers are facing are: What level of wastewater treatment has to be established in order to provide an adequate level of environmental protection? What kind of unit operations and processes have to be employed in order to achieve this task? To answer these questions detailed analysis of the local conditions and needs are required, application of scientific knowledge and engineering practice, with consideration of the current national regulation and legislation.

The methodology or the algorithm for the selection of the wastewater treatment technology is consistent with the stages as presented on the following figure. The practical application of this tool requires certain engineering knowledge from the user.

3.1.5.3 Input Data

The most important issue is the definition of the task that the planner or designer has to solve. The task could be defined only with accurate data collection and analysis. If data does not exist then data collection through measurements and observations has to be organised. The following input data have to be obtained prior to making any further decision:

» Obtaining existing technical and urban planning documentation for the water supply, wastewater collection, and treatment. Information on the existing water resources, facilities, and current performance of the water supply and wastewater infrastructure including water sources, water treatment, pumping stations, transmission, distribution and metering of potable water, population served, water consumption, water leakages, unaccounted for water, wastewater generation, wastewater collection and treatment and data on industrial activities. The majority of the above information is available within the Municipalities and/or public communal enterprises. The missing information will have to be obtained through site surveys and measurements;

» Definition of the agglomeration (described in detail in the subchapter below). The Contractor will develop Demographic Analysis of the agglomeration and determine the Population Equivalents of the agglomeration based on the population and industrial loads;

» Influent characteristics including wastewater quantity, flow rates, wastewater quality, and pollution loads. The pollutant load of the influent will be assessed on the base of the wastewater sample analysis taken from the wastewater discharges, domestic and industrial as well. The wastewater sample analysis will provide data regarding the physical, chemical, and bacteriological characteristics of the water. The most important pollution parameters would be: BOD_5, COD, TSS, TN, and TP;

» Water consumption and wastewater generation in the agglomeration and water demand analysis for the end of the design horizon of the plant resulting in future projections on the input data;

» Identification of the problems and priorities for the investment projects and improvements needed to meet future water demand;

» Determination of the WWTP capacity expressed as population equivalent (p.e.);

» Determination of effluent requirements hence the required percentage of reduction of the pollutants (treatment level). The target effluent quality standards for the WWTPs will be in compliance with the EU UWWTD and the national legislation

The analysis of the input data shall result in the determination of the WWTP capacity, effluent requirements, treatment level, and required percentage of reduction. The effluent standards are specific for each recipient depending on the local conditions, however, the effluent standards for most cases are already specified by the national legislation which is transposed from the EU legislation (Ministry of Environment and Physical Planning, 2011), (EC, 1991).

3.1.5.4 Definition of the agglomeration in the sense of EU UWWT Directive

Determination of the agglomeration of the wastewater collection and treatment projects is essential for the development of the wastewater infrastructure project. The term "agglomeration" is given in Article 2(4) of the UWWD: "Agglomeration" means an area where the population and/or economic activities are sufficiently concentrated for urban wastewater to be collected and conducted to an urban wastewater treatment plant or to a final discharge point.

The existence of an agglomeration is independent of the existence of the collecting system. Nor is the presence of an agglomeration related to the existence of a treatment plant. The existence of an agglomeration relates to a de facto situation of 'population and/or economic activities, which are sufficiently concentrated for urban wastewater to be collected and conducted to an urban wastewater treatment plant or a final discharge point'. The concept of agglomeration therefore also includes those areas which are sufficiently concentrated but where a collecting system is not yet in place. Moreover, because the demands of the Directive shall be fulfilled also in the future it is important to take the growth of the agglomeration into account when designing wastewater collection systems and urban wastewater treatment plants. Therefore, planning of investments becomes crucial in case of low connection rates and/or expansion of agglomerations.

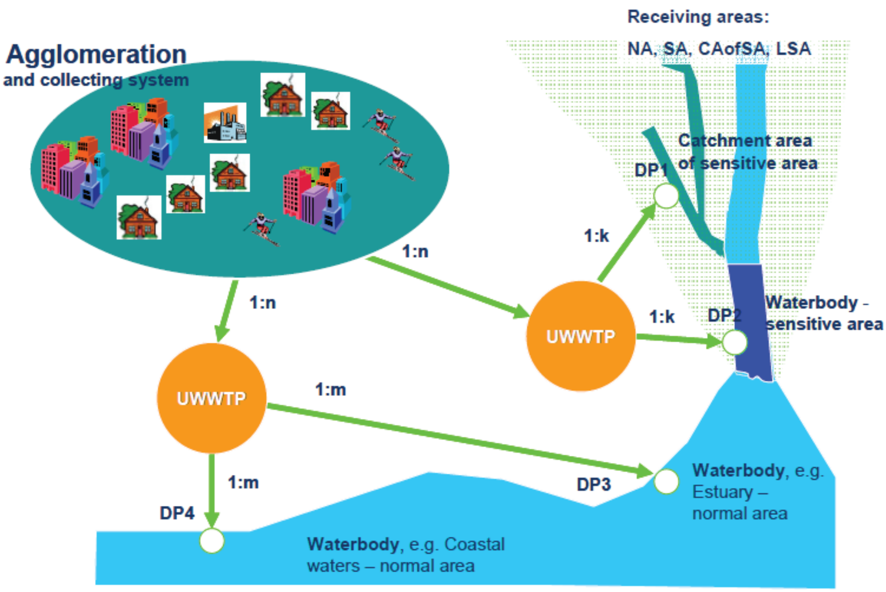


Figure 3-15 Agglomeration in the sense of UWWD

Agglomerations need to be determined on a case-by-case basis, and according to local conditions, the limits of each sufficiently concentrated area (i.e. agglomeration). During this process the criteria for identifying the agglomeration's limits shall be:

a) Concentration of population (e.g. population density per certain area)
b) Concentration of economic activities
c) Sufficient concentration of criterion a) or a) and b) for urban wastewater to be collected and conducted.

Regarding criterion c), it should be stressed out that the provision in question refers to the possibility from a technical point of view of collecting and conducting wastewater. Therefore, this criterion does not refer to the de facto situation of a collecting system being in a place or not.

The delineation of the agglomeration should therefore reflect the borders of the sufficiently concentrated area.

The term 'agglomeration' should not be confused with administrative entities (such as municipalities or other local authority areas), which may carry the same name. The limits of an agglomeration may or may not correspond to the boundaries of an administrative entity. Thus, several administrative entities could form one agglomeration, and vice versa – a single administrative entity may be covered by several distinct agglomerations if they represent sufficiently concentrated areas separated in space as a result of historical or economic developments. It should be underlined that an agglomeration may also contain areas that are sufficiently concentrated but where a collecting system is not yet in place and/or where wastewater is addressed through individual systems or other appropriate systems or collected in any other way.

For purposes of planning (including establishing and updating implementation programmes under Article 17 of the Directive), due attention is also to be paid to future extensions of an agglomeration, for example, due to population growth and/or increased economic activity. Therefore, the generated load and limits/ delineation of an agglomeration (i.e. the agglomeration's size in P.E.) should be regularly reviewed and updated.

All previous technical documentation and actual urban planning documentation should be taken into the consideration in order to better assess the existing situation and future forecasted development. The agglomerations are usually pre-determined at the national level. Even if this is the case, it will be the designer's duty to re-examine the agglomeration boundaries, and in this regard, to perform the following activities:

- Development of a number of options for the boundaries of the agglomerations, description of the technical, financial, social and institutional implications, and preparation of a SWOT analysis with recommendations of the optimal boundaries of the agglomerations in each case;
- Agreement of the agglomeration and its designation.

In summary, the agglomeration should include:

(1) Sufficiently concentrated areas where the collecting system (or systems) as laid down under Articles 2(5), 3 and Annex I.A is in place and wastewater is or should be conducted (or transported in case of an individual or other appropriate systems, IAS) to a treatment plant.

(2) Sufficiently concentrated areas where the collecting system is not in place. There are three possibilities:

(2.a) sufficiently concentrated areas where urban wastewater is addressed through individual or other appropriate systems which achieve the same level of environmental protection as a collecting system (i.e. not a “collecting system” according to Article 2(5) but conforming to Article 3(1) final sub-paragraph);

(2.b) sufficiently concentrated areas where urban wastewater is addressed through individual or other appropriate systems which do not achieve the same level of environmental protection as a collecting system (i.e. non-compliant); and

(2.c) other sufficiently concentrated areas, where urban wastewater is not addressed in any way (compliance yet to be achieved).

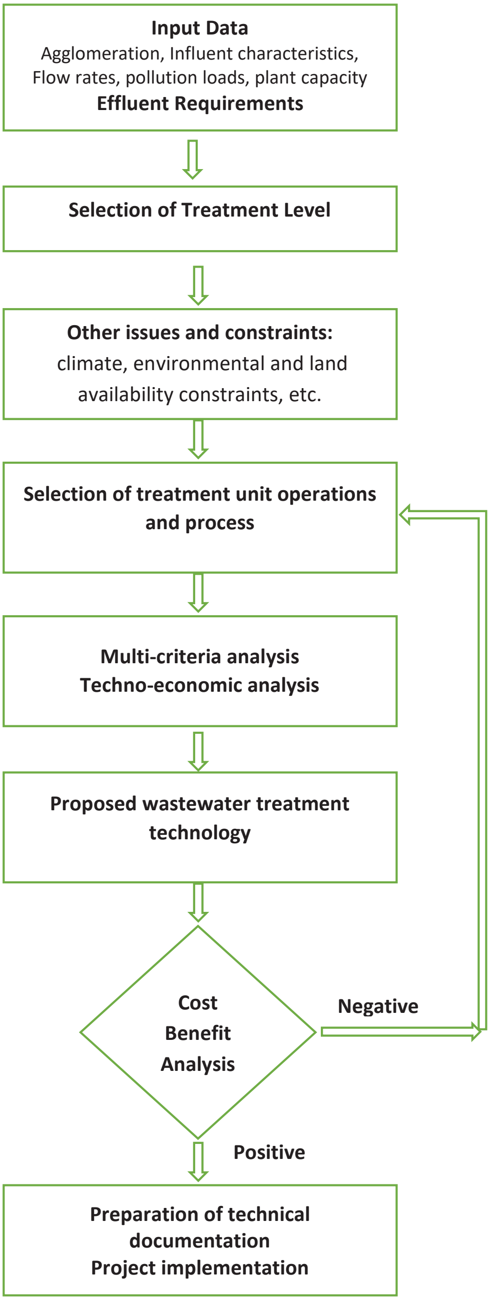


Figure 3-16 Algorithm for the selection of wastewater treatment technology

3.1.6 Treatment level, unit operations and processes and method of treatment

The next stage is the determination of the treatment level required to achieve the effluent requirements. Following treatment levels could be achieved: preliminary, primary, advanced primary, secondary, secondary with nutrients removal, tertiary, and advanced treatment as presented in the following table.

Municipal or urban wastewater treatment plants have to be constructed to achieve a certain treatment level depending on the capacity and recipient. According to the EC Directive (91/271/EEC) (EC, 1991), EU Member states have to respect the following:

» urban wastewater entering collecting systems shall before discharge be subject to at least secondary treatment or an equivalent treatment as follows:
  - all discharges from agglomerations above 15.000 p.e.,
  - all discharges from agglomerations of between 10.000 and 15.000 p.e.,
  - for discharges to fresh-water and estuaries from agglomerations of between 2000 and 10 000 p.e.

» urban wastewater entering collecting systems shall before discharge into sensitive areas be subject to more stringent treatment (nutrients removal) than that described in bullet 1, for all discharges from agglomerations of more than 10 000 p.e.

» urban wastewater discharges from agglomerations of between 10 000 and 150 000 p.e. to coastal waters and those from agglomerations of between 2 000 and 10 000 p.e. to estuaries situated in the less sensitive areas may be subjected to treatment less stringent than that in bullet 1, providing that such discharges receive at least primary treatment and comprehensive studies indicate that such discharges will not adversely affect the environment.

» urban wastewater discharges to waters situated in high mountain regions (over 1 500 m above sea level) where it is difficult to apply an effective biological treatment due to low temperatures may be subjected to less stringent treatment than those prescribed in bullet 1, provided that detailed studies indicate that such discharges do not adversely affect the environment.

The common pollutants found in the municipal wastewater are suspended solids, biodegradable and volatile organic material, nutrients, colloidal and dissolved solids and pathogens, which could be removed by physical, chemical, or biological methods. The individual methods are classified as physical unit operations and biological and chemical unit processes. Today, there is large number of stand-alone wastewater treatment methods for the removal of the common pollutants that are divided into unit operations and processes. The individual unit processes are grouped together, and depending on the combination various treatment levels could be achieved, as presented in the following table (Tchobanoglus, et al., 2003).

Table 3-6 Treatment levels, constituents, unit operations, and processes

Level	Constituent	Unit operation or process
Preliminary	Solis waste, grit, grease, suspended solids	Screening
		Grit removal
		Sedimentation
Primary	Suspended solids and organic matter	High-rate clarification
Advanced Primary	Enhanced removal of suspended solids and organic matter	Flotation
		Chemical precipitation
		Depth filtration
		Surface filtration
Secondary	Removal of biodegradable organic matter (in solution or suspension) and suspended solids.	Aerobic suspended growth variations
		Aerobic attached growth variations
		Anaerobic suspended growth variations
		Anaerobic attached growth variations
		Lagoon variations
		Physical-chemical systems
		Chemical oxidation
		Advanced oxidation
		Membrane filtration
Secondary with nutrient removal (Tertiary)	Biodegradable organics, suspended solids and nutrients (nitrogen, phosphorus, or both nitrogen and phosphorus) Nitrogen	Chemical oxidation (breakpoint chlorination)
		Suspended-growth nitrification and denitrification variations
		Fixed-film nitrification and denitrification variations
		Air striping
		Ion exchange
	Phosphorus	Chemical treatment
		Biological phosphorus removal
	Nitrogen and phosphorus	Biological nutrient removal variations
Tertiary	Pathogens	Chlorine compounds
		Chlorine dioxide
		Ozone
		Ultraviolet (UV) radiation
	Residual solids	Granular medium filtration
		Microscreens

Advanced	Colloidal and dissolved solids	Membranes
		Chemical treatment
		Carbon adsorption
		Ion exchange
	Volatile organic compounds	Air striping
		Carbon adsorption
		Advanced oxidation
	Odours	Chemical scrubbers
		Carbon adsorption
		Biofilters
		Compost filters
Sludge treatment		Gravity thickening
		Chemically enhanced thickening
		Sludge digestion lagoons
		Aerobic sludge digestion
		Anaerobic sludge digestion
		Mechanical dewatering
		Sludge drying beds

Other issues and constraints that could be specific for the certain case scenario, have to be addressed before the selection of various alternatives for treatment technology:

» **Climatic constraints:** The temperature affects the rate of reaction of most chemical and biological processes. Temperature may also affect the physical operation of the facilities. Warm temperatures may accelerate odour generation and also limit atmospheric dispersion;

» **Environmental constraints:** Environmental factors, such as prevailing winds and wind directions and proximity to residential areas, may restrict or affect the use of certain processes, especially where odours may be produced. Noise limitations may affect the selection of treatment processes. Receiving waters may have special limitations, requiring the removal of specific constituents such as nutrients;

» **Land availability** and the possibility for acquisition is a very important factor that may determine the treatment technology as some require relatively small and some large land area.

3.1.7 Treatment technology selection

The main criteria to define the type of plant are the origin and composition of the wastewater, requirements in terms of quality of treated wastewater to match the characteristics of the recipient, and the suitability of the chosen unit processes to be implemented in practice. Considering the complexity of the problem, implementation of different physical, chemical, and biological processes is necessary. The selection of the treatment operations and processes that shall be further evaluated is based on the established engineering practice for different case scenarios.

Guidelines for the establishment of technological process conception are given in the form of EU Directive through the Best Available Techniques (BAT standards) (EU, n.d.). The term - Best Available Techniques, has the following meanings:

» Technique is the way in which the treatment plant is designed, built, maintained, functioning and decommissioned or closed, including the used technology;

» Availability means that the technique is developed at the level that allows implementation in a particular sector, under economically and technically viable conditions, including costs and benefits; and

» Achieving a generally high level of protection of the environment in the most efficient way has been described as the best.

An overview of technologies considered as the best available technologies for primary, secondary, and tertiary treatment of urban wastewater in dependence on the number of PE, which will be used as a guideline for preliminary selection of the treatment processes is presented in the following table.

At this stage, on the basis of the input data on the influent characteristics, effluent requirements and based on the experience and literature guidelines the planner or the designer selects several alternative wastewater treatment technologies for the actual case. Because the waste sludge produced varies with the kind of treatment system, the designer has to select the desired method of sludge treatment, disposal or reuse. Processes for sludge stabilization and dewatering are then selected based on both wastewater treatment technology and method of sludge disposal, or reuse.

Usually, more than one technology or process are qualified as appropriate. It is proposed to select three to five treatment technologies that can be further analysed.

Table 3-7 Best Available Technologies for urban wastewater treatment plants

WWTP capacity			
Up to 1,000 PE	**1,000 ÷ 10,000 PE**	**10,000 ÷ 50,000 PE**	**More than 50,000 PE**
PRELIMINARY AND PRIMARY PHASE			
- Straining through coarse screen fine screen	- Straining through coarse screen fine screen	- Straining through coarse screen fine screen	- Straining through coarse screen fine screen
- Straining through the sieve Perforation above 2mm	Straining through the sieve Perforation above 2mm	- Straining through the sieve Perforation above 2mm	- Straining through the sieve Perforation above 2mm
- Primary settling Two-stage settling	- Sand removal gravitational - Oil and grease removal gravitational	- Sand removal gravitational aerated sand trap aerated sand trap with oil and grease removal	- Sand and oil and grease (combined) removal gravitational aerated sand trap, aerated sand trap with oil and grease removal
			- Primary sedimentation
SECONDARY – BIOLOGICAL PHASE			
- Processes based on natural processes (extended processes) natural lagoons wetlands landfill	- Processes with fixed biomass rotational and biological contactor with more units (low loaded)	- Processes with fixed biomass rotational and biological contactor with more units (low, medium, and highly loaded) two-stage biological filters (highly and low loaded)	- Processes with activated sludge with nitrification two stage procedures (heavy loaded, lightly loaded)
- Processes with fixed biomass rotation biological contractors, biological filters (light loaded) - Processes with activated sludge total oxidation aerobic-anaerobic	- Processes with activated sludge aerated lagoons total oxidation	- Processes with activated sludge total oxidation with nitrification	
TERTIARY PHASE			
		Biological denitrification pre-denitrification, step feed, simultaneous alternative intermittent	Biological denitrification pre-denitrification, step feed, simultaneous alternative intermittent
		- Phosphorous removal biological (simultaneous chemical if necessary)	Phosphorous removal biological + simultaneous chemical if necessary
		- Disinfection chlorine reagents (Cl_2, NaOCl), UV	

3.1.8 Techno-economic and multi-criteria analysis

Having selected multiple treatment technologies that shall produce adequate effluent quality it is of utmost importance to select the best technological option for further implementation.

The next stage in the methodology is to analyse monetary criteria like investment, operation and maintenance cost through techno-economic analysis. For this purpose, the designer has to develop conceptual designs of the pre-selected treatment technologies, meaning to develop: layouts, process diagrams, estimation of investment costs, and estimation of the operation, and maintenance (O&M) costs, which include: annual level for energy consumption, materials and chemicals consumption, repairs and maintenance cost and salaries. Not always the cheapest investment technology is the most beneficial, as the operational and maintenance cost may prevail over longer periods of time.

Based on the developed conceptual designs and calculation of investment and O&M costs, Net Present Value (NPV) should be calculated in order to justify which of them would be the economically most advantageous option. The NPV computes the different discounted values of investment costs and operating costs taking into account the structure of the capital investments and accordingly the size and timing of capital replacement costs. For mechanical and electrical equipment, a lifetime of 15 years was assumed, with full replacement costs after 15 years. The option of demonstrating the smallest NPV is the most advantageous one.

Further analysis of the non-monetary criteria should be developed, which would better clarify the best treatment technology. A list of non-monetary criteria is proposed, divided into the four main criteria, with each main criterion divided into appropriate sub-criteria:

- **General Issues:** Technology commonly used for the similar capacity, Existing experiences in the country/region, Construction simplicity, Land requirements, Ease of addition of further process streams, Treatment efficiency;
- **Operation & Maintenance:** Simplicity of the operational start-up-phase, Ease to operate, Requirement of external expertise, Energy demand, Requirement of spare parts, Grade of automation
- **Process Reliability:** Effect of plant failure, Ability to adjust processes, Reaction to shock loads, Formation of scum, Formation of bulking sludge
- **Sludge Handling:** Quality of sludge produced, Quantity of sludge for disposal, Ability to restart treatment process after inhibition, Energy recovery.

Each sub-criterion is assigned with a corresponding weight, considering that the more important the criterium is the higher weight is assigned to it, representing its relative importance in ensuring the continued sustainability of the WWTP. Then, based on the engineering experience and based on the advantages and disadvantages of certain treatment technology for the given case, the evaluators are giving grades to each sub-criterion: for example, 1 (good) to 5 (poor). The final value for each sub-criterion is acquired by multiplying the weight value with the grade value, resulting in the smallest total value is the most advantageous.

If both analysis results are proposing the same technology as the most appropriate, then the outcome is clear. In case when the techno-economic and multi-criteria analyses are proposing different technologies, the final ranking of each of the proposed technologies could be performed based on the final scoring of:

- Multi-criteria analysis of non-monetary criteria is weighted with 40%. The final score for each treatment technology shall be calculated like: = (lowest Total Evaluation points / Total Evaluation Points for the evaluated technology) x 40
- NPV is weighted with 60%. The final score for each treatment technology shall be calculated like: (lowest NPV / NPV for the evaluated technology) x 60.

Final ranking points will be the sum of the final scores for the above non-monetary and monetary criteria. The treatment technology with the highest Total Ranking Points is recommended as the most appropriate wastewater treatment technology for any case scenario. It is recommended to prepare a full Cost Benefit Analysis for the selected technology.

3.1.9 Cost-benefit analysis

CBA is an essential tool for estimating the economic benefits of projects. In principle, all impacts should be assessed: financial, economic, social, environmental, etc. The objective of CBA is to identify and monetise (i.e. attach a monetary value to) all possible impacts to determine the project costs and benefits; then the results are aggregated (net benefits) and conclusions are drawn on whether the project is desirable and worth implementing. If the analysis is positive then the project may be implemented, and if not then the planner or designer has to repeat the whole process of selection of treatment operations and processes.

When estimating the potential impacts of a project, analysts always face uncertainty. This must be properly taken into account and dealt with in CBA. A risk assessment exercise is an essential part of a comprehensive analysis, as it enables the project promoter to better understand the way the estimated impacts are likely to change should some key project variables turn out to be different from those expected. A thorough risk analysis constitutes the basis for a sound risk-management strategy, which in turn feeds back into the project design.

3.1.10 Preparation of technical designs

Depending on the needs during the project development, various types of design documentation will be required:

- Studies (Feasibility Study, Environmental Impact Assessment Study, Cost-benefit Analysis)
- Site survey and measurements (topographic surveys, geotechnical and geo-mechanical investigations of the soil, hydrology and hydrogeology studies, wastewater flow measurements, wastewater quality analysis)
- Conceptual design (usually required at the preparation stage. It is developed at such level of details to enable comparison of several treatment technologies. Should provide cost estimate accuracy of ±30%)
- Preliminary design (depending on the needs it may be developed in the preparation or prior to the construction stage. Should provide cost estimate accuracy of ±20%)
- Detailed design (usually prepared for the execution of the works during the construction stage. Should provide cost estimate accuracy of ±10%)
- Other design documents (workshop details, as-build documentation)

Preparation of the technical documentation for the wastewater collection and treatment project is a multi-disciplinary activity, which involves all engineering disciplines, as presented in the following figure.

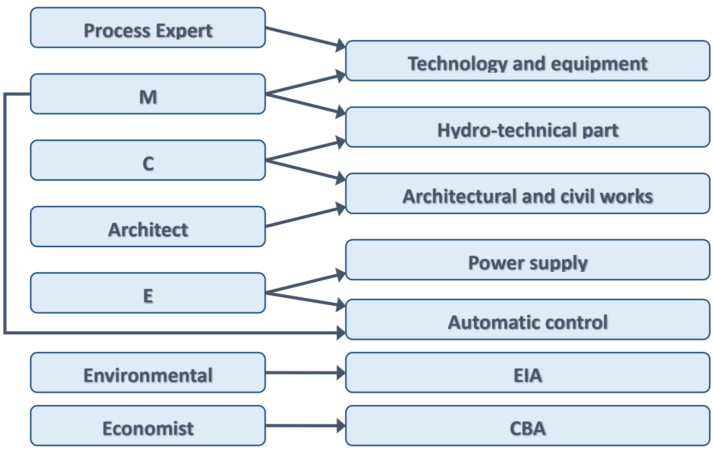


Figure 3-17 Multi-disciplinary team of experts needed for the development of WWTP projects

Common contaminants in wastewater at treatment plants are separated or reduced through physical, chemical, and biological processes. Today, there are numerous wastewater treatment methods that are divided into individual units and processes. Different levels of treatment can be performed depending on the needs.

The most significant are the treatment plants where the biological treatment takes place with the process of active sludge. The following typical wastewater treatment processes take place in an activated sludge treatment plant:

» Preliminary treatment - most often this part includes the inlet pumping station, as well as mechanical separation of large waste with the help of large and fine grate, sand and oil separators;
» Primary treatment - primary sediments and equipment for pumping and drainage of primary sludge, as well as dosing of chemicals (iron to remove phosphorus or coagulants due to increased deposition of solids);
» Secondary treatment - biological treatment of wastewater usually through the process with activated sludge in aerated tanks. Reduction of organic matter and nutrients through appropriate chemical or biological processes through the use of microorganisms. The biodegradable part of the matter is broken down by microorganisms in the presence of oxygen. Removal of the biological part from nitrogen compounds is a two-step process involving nitrification and denitrification. The microorganisms are separated in a secondary precipitate from where some are returned to the process by recirculating the sludge, and some are removed and taken to the sludge treatment line. The equipment required for the operation of this phase of the treatment includes pumping (recirculation of active sludge), mixers, blowers, equipment for removal of accumulated sludge.
» Tertiary treatment - Additional filtration or polishing of the effluent (additional nitrification). Disinfection of purified water before discharge into the recipient to reduce the number of microorganisms. Disinfection can be done by chlorination, UV radiation, or ozonation.
» Treatment of excess sludge - Thickening and dehydration of sludge. Sludge stabilization by anaerobic or aerobic processes. Energy recovery by obtaining biogas from anaerobic digestion or obtaining thermal energy by incubation of dried sludge.
» Air treatment - includes equipment that serves for the extraction of air from closed rooms in which the mechanical treatment of wastewater and the treatment of sludge and its purification take place, i.e. relief from unpleasant odor.

3.2. Issues for transnational consultation

A joint agreement between countries is of high importance to implement the European Environmental Directives with regards to the water management for the international Axios River Basin. There are existing joint monitoring networks of environmental parameters which only require further coupling and improvement. Additionally, coordination between the countries is necessary in order to achieve the objectives of the Directive in the Axios River Basin in the program period (2015-2021). That means that a joint river basin management plan in the program period 2021 – 2027 must be created and implemented. A Crisis Management plan follows from there, for which a joint action plan for emergencies (e.g. industrial accidents, extreme droughts, floods) has to be implemented.

3.3 Risk response goals for WWT Risks

The risk response plan allows wastewater control according to the volume or to the destination of wastewater to create an economy of scale in the WWT (Xenidis, 2017).

Sewerage and wastewater treatment services in countries are facing a large rural population and therefore the dispersed settlements can be developed at an individual level or on the cooperative model through appropriate incentive mechanisms. Decentralization the participation of the citizens in the wastewater treatment process can be of high favor for WWTP management.

Developing wastewater treatment infrastructures can be facilitated by legislation regulating this kind of complex ventures. Therefore, a dedicated unit in the structure of government can be useful to expedite the administration of PPP ventures.

WWT costs vary according to the final destination and use of the recycled water; therefore, the differentiation of standards of treatment per case may be extremely effective, encouraging uptake by the end-users.

In order to proactively protect human and environmental health, it is necessary to:

- Address the risk assessment-based approach to the setting of wastewater treatment standards;
- Pursue progressive and continuous evaluation of standards because the threats constantly evolve;
- Increasing the general awareness in order to expect results of a strong commitment to policies implementation;

- Have transparent processes, public participation, and universal access to information, as they are an important adjunct to legal frameworks related to wastewater management;
- Have integrated legal provisions to a comprehensive framework in order to ensure the sustainability of the answers given to the wastewater challenge;
- Have stable institutional coordination both at the level of decision-making and the level of implementation;
- Establish integrated permit systems for wastewater discharges, preferably administered by a central authority;
- Have mixed sanctions for violations and non-conforming behaviors in WWT with incentives or acknowledgement of good performance;
- Adapt the technologies implemented in WWT to the national/ local context;
- Implement low-cost natural treatment technologies in the rural areas of developing countries;
- Establish permanent international river basins institutions (in transboundary cooperation) in order to implement common and effective policies;
- Keep a proper balance between central and decentralized approaches;
- Focus on the national level to effectively achieve international co-operation;
- Have flexible mechanisms for risk response, funding, and standardization

3.3.1 Integrated River Basin Management

The integrated river basin management in the EU has gone through several stages as follows (Dimoska Zajkov, 2017):

- The first wave of water legislation
    - 1975: standards for rivers & lakes used for drinking water abstraction
    - 1980: binding quality targets for drinking water
- The second wave (1990s)
    - Urban Wastewater Treatment Directive (1991)
    - Nitrates Directive (1991)
    - New Drinking Water Directive (1998)
    - IPPC Directive (1996)
- 1995: need to re-think European water policy & for more comprehensive legislation
- Oct 2000: Final adoption of WFD by a joint decision by the European Parliament & Council (“co-decision procedure”) and following a conciliation procedure
- 22 Dec 2000: Publication & entry into force

The process of water regulations adaptation in North Macedonia is as follows:

In 2003 the MoEPP supported by the EU-funded Project "Strengthening the capacity of the Ministry of environment and physical planning "prepared Water Law in order to harmonize the national legislation to the Environmental Acquis. During the preparation of the law, the following EU Directives were taken as a basis:

» The Water Framework Directive 2000/60/EC including the Decision 2455/2001/EC;
» The bathing water directive 76/160/EEC;
» Water intended for human consumption Directive 98/83/EC;
» Urban wastewater treatment directive 98/15/EC;
» Nitrate Directive 91/676/EEC;
» Sludge directive 86/278/EEC, and other relevant directives.

The existing national water legislation of North Macedonia is:

» Law on Waters – start to implement from 01.01.2011
» Under the Law on Waters ("Official Gazette of North Macedonia" (No.87/2008), more than 30 sub-legislation acts have been adopted, regards of (WFD, UW-WTD, Sludge Dir., Nitrate Dir., Dangerous sub, etc.)
» Ministry of Environment and Physical Planning was reorganized in order to establish separate divisions for each river basin in the country. For this purpose, the new structure of the water sector was adopted, and 6 divisions were formed: Division of Planning in water management, Division of Water Rights, Division of Concessions and inter-department cooperation, Division for management of Vardar river basin District, Division for management of Crn Drim and Division for management of Strumica river basin District.

The way of communicating and reporting the issues related to water goes as shown on the scheme below:

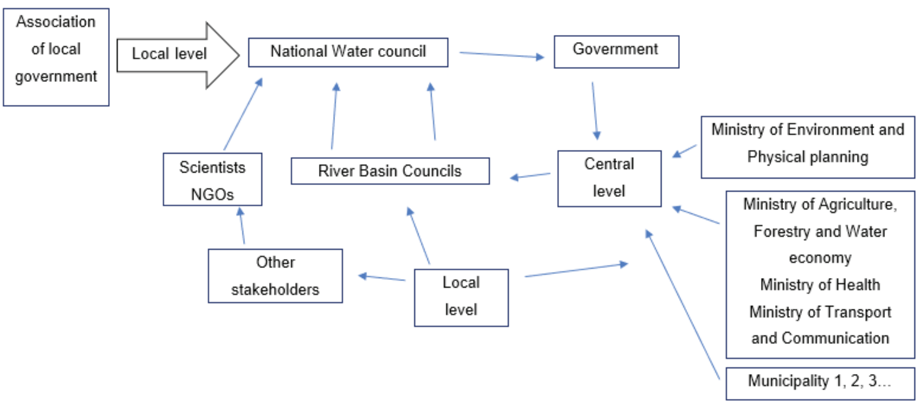


Figure 3-18 Schematic overview of the communicational flow

3.3.2 Register of protected areas

There are registered protected area of the country which has been protected under the following directives:

- Waters used for the abstraction of drinking water protected areas designated under the Water Framework Directive (2000/60/EC) that were previously protected by the Surface Water Abstraction Directive (75/440/EEC)

Areas under the Urban Waste Water Treatment Directive (91/271/EEC).

- Areas designated for the protection of habitats or species aquatic part of Natura 2000 sites designated under the Birds Directive (79/409/EEC) and the Habitats Directive (92/43/EEC)
- Bathing waters Bathing Water Directive (2006/7/EC)
- Areas designated to protect economically significant species protecting shellfish (79/923/EEC) and freshwater fish (78/659/EEC).

3.3.3 Wastewater reclamation and reuse

Wastewater reclamation is the process of converting wastewater into water that can be reused for other purposes (Figure 3-19).

Figure 3-19 Reclaimed water (By Wateralex - Own work, CC BY-SA 4.0) [10]

10 Source: https://commons.wikimedia.org/w/index.php?curid=45828357

Water reuse includes

- Irrigation of gardens
- Irrigation of agricultural fields
- Industrial water
- Replenishing surface water and groundwater (i.e. groundwater recharge)
- Wetland support
- May also be directed toward fulfilling certain needs in residences (e.g. toilet flushing), businesses and industry
- Direct or indirect water supply (which is a particular challenge)

The irrigation in agriculture with reused treated wastewater is worldwide spread, as clearly demonstrated in the following Table:

Table 3-8 Countries that are using treated wastewater for irrigation

Countries	Irrigation (hectares)
China	13.330.000
Mexico	3.400.000
India	855.000
Germany	280.000
Chile	160.000
USA	134.750
Kuwait	120.000
Australia	100.000
Israel	88.000
Tunisia	73.500
Peru	68.000
Morocco	60.000
Argentina	57.000
Saudi Arabia	28.500
Sudan	28.000
S. Africa	18.000

Finally, reused water can even be treated to reach drinking water standards. This last option is called either *"direct potable reuse"* or *"indirect potable reuse"*, depending on the approach used. In the following chart, advanced treatment is succeeding the conventional secondary and tertiary treatment of wastewater. After the granular media filtration of the tertiary treatment, membrane filtration and reverse osmosis may be applied. With the addition of hydrogen peroxide, advanced oxidation can be applied, before the purified water is produced (Tchobanoglus, et al., 2003).

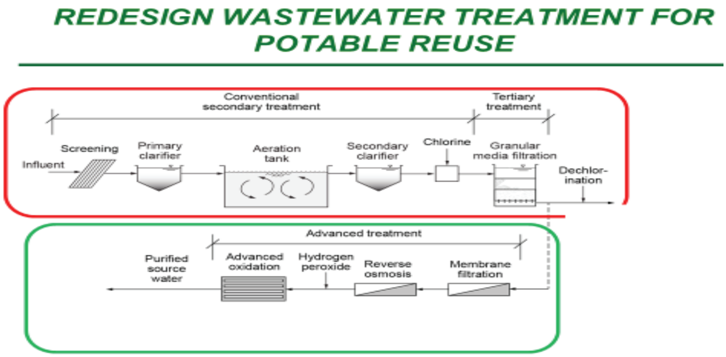


Figure 3-20 Advanced treatment technology towards the production of potable water (Tchobanoglous, 2017)

Conclusively, urban wastewater management is considered sustainable and viable if it has the ability to redirect its effluents in all possible uses (Figure 3-21) (Zafirakou, 2017), i.e. biologically treated wastewater can be used in the industry or agriculture, advanced treated wastewater can be used for potable use; treated wastewater can be used in agriculture and the industry. In addition to those, rainwater and freshwater can be used to dilute treated wastewater; desalinated water can be mixed with groundwater or treated surface water, in order to be used as potable or for agriculture.

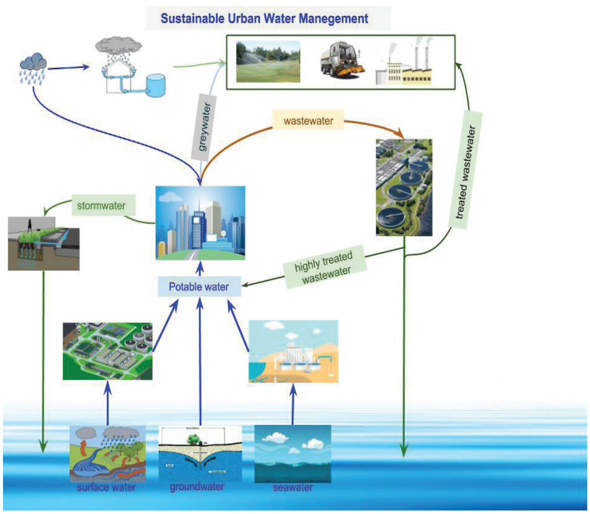


Figure 3-21 Sustainable urban water management (Zafirakou, 2017)

3.4 Wastewater treatment in North Macedonia

WWTPs which were built and are functioning in North Macedonia are presented in Table 3-9, where also WWTPs that are planned for construction in the next period of 5 - 10 years are presented. The construction of these WWTPs in North Macedonia will provide wastewater treatment in the largest agglomerations. The next step will be the construction of WWTP for smaller settlements (Jovanoski K, 2018).

Table 3-9 Functioning Wastewater Treatment Plants in North Macedonia

WWTP	Population Equivalent	Treatment Level	Projected costs of EE (kWh/a)	Status[11]
Vranishta	120.000	Secondary	2.000.000	Active from 1988
Nov Dojran	12.000	Secondary	/	1988
Kumanovo	90.000	Tertiary	1.800.000	2006
M. Brod	3.000	Secondary	65.000	2000
Berovo	14.000	Secondary	200.000	2010
Resen	10.000	Secondary	135.000	2005
Volkovo	19.500	Secondary	/	2016
Prilep	95.000	Secondary	4.420.000	2019
Gevgelija	30.000	Secondary	3.400.000	2018
Strumica	56,000	Secondary	/	2017
Radovish	25,000	Secondary	/	2017
Kicevo	32,000	Secondary	/	2018
Kocani	65,000	Secondary	/	2019
Tetovo	100,000	Secondary	/	In preparation phase
Bitola	110,000	Secondary	/	In preparation phase

3.4.1 River basins in North Macedonia

The hydrographical territory, as shown in Figure 3-22, belongs to the following river basins: the Vardar river basin covering the largest part of the country territory gravitates towards the Aegean Sea, the Crn Drim river basin, comprising the Prespa and Ohrid lake basins, gravitates to the Adriatic Sea and the Strumica river basin gravitates to the Aegean Sea. A negligible part of the hydrographical territory drains to the Danube river basin with the Juzna Morava river basin. There are three major natural lakes: Ohrid, Prespa, and Dojran.

11 Data up to 2019

Figure 3-22 River basins in North Macedonia

3.4.2 Vardar River – shared economic benefits

In North Macedonia

The Vardar River has a significant role in the national economy. Almost all of the economic activities depend on the river. It is the largest river body in North Macedonia which basin covers almost 90% of the country, running through the biggest cities: Skopje (pop.530,258), Veles (pop.55,108), Negotino (19,212), and Gevgelija (15,685). The river is used for energy production from hydropower which makes it important for the national economy. Its water management is done according to EUWFD guidelines.

In Greece

The River Vardar is important for the regional development. A significant 85% of the shellfish production of the country is in the Vardar River. It is also an estuary of unique ecological significance–rare flora & fauna.

3.4.2.1 Agriculture

The river has a very significant impact on agriculture in both countries. Its shared value is just one example of the importance of bilateral management and protection.

The impact on agriculture in North Macedonia is as follows:

- There are water quality issues in the whole river basin;
- The threat of eutrophication phenomenon (environmentally sensitive areas) exists;
- There is a threat for the monoculture of shellfish & mussels in Axios estuary

On the other side, the impact in the Greece part is:

- Down drawn of the water table

There are recommended responses to these issues that can improve the situation:

- Implement common water management plan;
- Implement join monitoring systems;
- Reorientation of crop patterns on both sides;
- Optimization of projects
- Build joint research projects/information campaigns and training of farmers through seminars

3.4.2.2 Industry

The Vardar river also influences the industry possibilities and states in both countries. The impact that it has in both countries is:

- There are water quality issues in the whole river basin;
- The threat for the sensitive ecosystems and biodiversity exists;
- The threat for monoculture of shellfish & mussels in Axios estuary.

Responses in favour of the basin that can be implemented are:

- A perspective of a common water management plan;
- A common crisis management plan

3.4.2.3 Water supply

Vardar river participates in the water supply in both countries; therefore, its quality is of utmost importance. The impact that it has is as follows:

- There is water quality degradation;
- There is a threat for sensitive ecosystems & biodiversity

The response to improving the situation can be a perspective of a common water management plan. Also, Greece can provide expertise, know-how& investments for the construction of projects for the improvement of water quality (WWTP, sewage networks)

3.4.2.4 Cattle Breeding/Shellfish and Mussels Production

Threats are present in both countries regarding the cattle breeding/shellfish and mussel's production. There are pasture areas in North Macedonia, the groundwaters can be harmful and the biodiversity can be destroyed.

While in Greece the threats are a monoculture of shellfish and mussels (Algae blooms) and the sensitive estuary's ecosystem.

Same as above the response for improving the situation can be a perspective of a common water management plan. Also, Greece can provide expertise, know-how & investments for the construction of projects for the improvement of water quality (WWTP, sewage networks)

3.4.2.5 River Accumulations/Alterations – Energy production

The impacts from the river accumulations for energy production in North Macedonia are:

» Alteration in water quantity
» The threat for the ecological flow and the preservation of the sensitive ecosystems (Axios estuary);

While in Greece they are:

» Signs of water scarcity (particularly in summer);
» Agricultural production is at risk;
» The sensitive ecosystem of the protected Axios estuary is at risk.

The responses for managing the situation are perspective of a common water management plan and planning of hydraulic works based on sharing benefit on both countries.

3.5 Case study Skopje

This chapter is providing an overview of the existing situation with the wastewater collection and treatment in the City of Skopje, proposed measures for improvement of the wastewater collection, and construction of a new central WWTP for the major part of the City of Skopje. The main source of information used in this chapter are the latest Feasibility studies:

» Feasibility Study and Cost-Benefit Analysis for Improvement of the Wastewater Collection Infrastructure in the City of Skopje, Prepared by SAFEGE, November 2015; (Tmusic, 2015)

» Feasibility study for financing, construction, and operation of WWTP for the City of Skopje, Prepared by EGIS and BAR E.C.E., December 2014 (Kassis & Letessier, 2014)

The following text represents the summary of the comprehensive analysis conducted within the two above mentioned Feasibility studies.

3.5.1 Current status of the wastewater infrastructure

The City of Skopje is the capital of North Macedonia, located in the northern part of the country. It is grouping 10 municipalities covering an area of 571.46 km^2 including an urban area of 225 km^2, with an estimated population of around 600,000 inhabitants in 2017. Skopje is the most important city and the centre of the country's economy and industry. Household wastewater, the wastewater for industry, and agriculture all end up in the Vardar River, mainly without treatment, as the largest drainage artery in the region (Egis Eau; BAR E.C.E. Skopje, 2017).

Figure 3-23 Location of the City of Skopje

3.5.2 Existing wastewater treatment facilities

Most of the major cities in North Macedonia, including the capital Skopje, do not have central urban wastewater treatment facilities. Skopje is located in the Vardar

River hydrography catchment basin which covers almost 80% of the total surface of the Country and flows into the Aegean Sea after entering the Greece territory.

On the city territory there are four existing small size municipal WWTPs: two non - operational plants in the semi-urban Saraj municipal area, one in Volkovo, under construction, to serve the northern part of Gjorce Petrov Municipality also part of the City of Skopje, one old, also non – operational in Dracevo. However, there is an existing industrial wastewater pre-treatment present in almost all major industries.

3.5.3 Existing wastewater collection infrastructure

The sewerage system in the City of Skopje is originally designed as a separate system for the collection and transport of wastewater and stormwater. Major construction of the wastewater collection system began following the earthquake which happened in 1963, and the development of the stormwater sewerage started in the second half of the 1960s.

The City of Skopje is made of ten municipalities divided into four sewer districts (wastewater catchment areas):

- Central district;
- Saraj district;
- North - Gjorce Petrov district; and
- Drachevo district,

All districts will have independent wastewater collection systems with separate solutions for wastewater treatment.

Currently, the total length of the existing sewerage network is 1,021 km (wastewater network and stormwater network) and the existing wastewater infrastructure covers 80% of the population. The rest of the population (20%) has either septic tanks or uncontrolled discharges of wastewater.

The wastewater is discharged into the river Vardar through 6 legal and many illegal discharge points between 40 and 60 illegal discharge points). The current discharge system is designed as a separate one with two main trunks located on the left and right banks of the Vardar. Existing industry plants are either connected to the wastewater network or equipped with their own local sewers with separate discharges into the river Vardar.

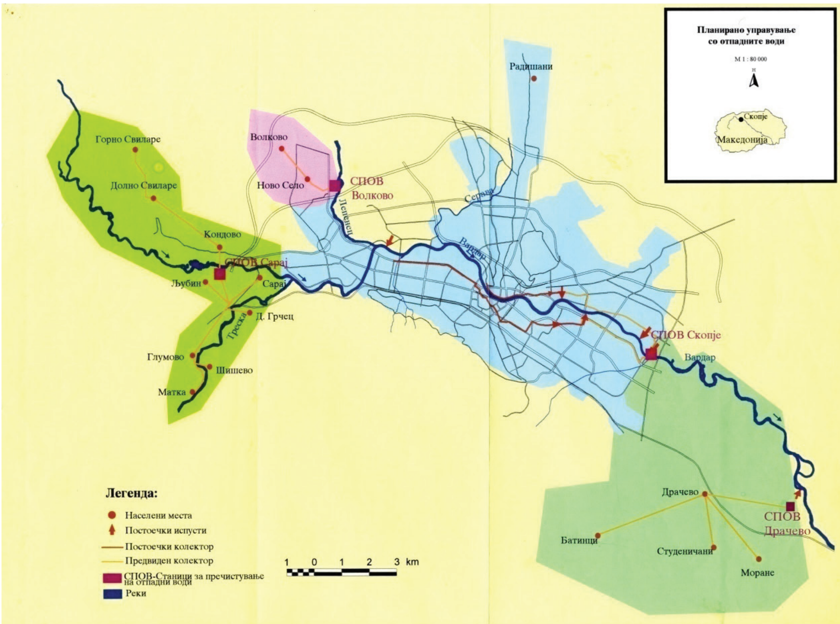


Figure 3-24 Sewer districts in the City of Skopje

In comparison to the national statistical figures, the rate of connection to the sewer system in Skopje City is higher than the national average rate established at 75% according to Analytica for 2009. The population not connected to the sewer network is using on-site sanitation facilities, more particularly septic tanks or cesspits; otherwise, the generated sewage flow of non-connected users is directly discharged into the nearby drainage canal.

Regarding the storm drainage, in practice, only 50% of the catchment area has storm drainage, and the total length of the existing storm drainage is 302 km. There is insufficient development of the storm drainage which causes overloading of the sewerage system in rainy periods. Since the stormwater networks have not been completely developed, significant amount of the stormwater enters the wastewater sewerage network. Overloading of the sewers used as combined sewers has been controlled by overflows that directly discharge the excess water into the river Vardar.

The wastewater is collected into two main trunks located on the left and right banks of the Vardar. The wastewater from these main trunks is discharged without any treatment directly into the river Vardar in the area of “Pivara Skopje” (Brewery), on the left bank, and in Boulevard Srbija, on the right bank. As already stated, in addition to 6 legal discharge locations and 4 overflows, there are numerous outlets of either wastewater or combined wastewaters and storm waters on both banks of the Vardar. The greater part of the outlets is located in the city centre.

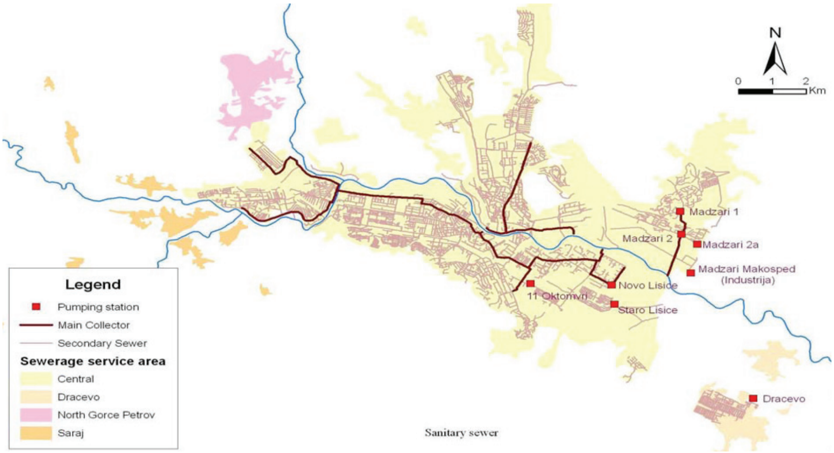


Figure 3-25 Existing wastewater collection infrastructure

Collectors are of various materials and show very often cracks from where underground water infiltrates the line. Pipe joints are also showing some weakness which is also exacerbating the groundwater infiltration into the system. The discharge of stormwater into sewer lines in areas where stormwater drainage collectors are not available is definitely overloading sewer lines. This issue is far to be solved due to limited investment on both sewer lines: sewage and stormwater collectors.

The wastewater collection system in Skopje has also eight pumping stations but only five of them are in operation. The other three pumping stations are operating with difficulties.

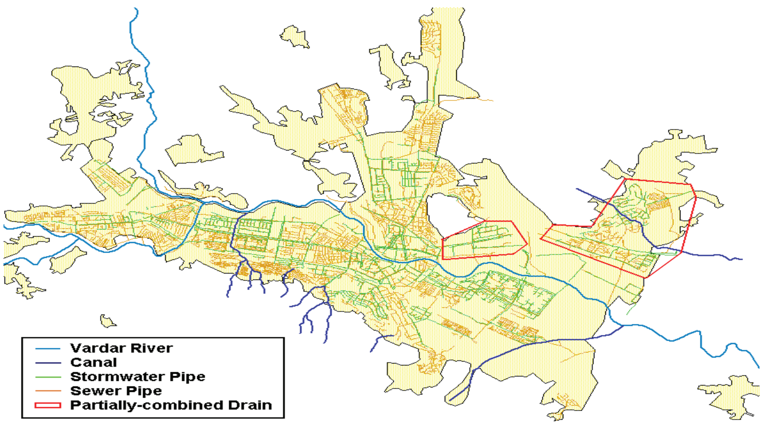


Figure 3-26 Existing storm drainage infrastructure

Based on a review of available documentation and data, as well as an insight into the current situation based on the on-site investigation including CCTV inspection, the main issues concerning the existing sewerage system are the following:

- Quantities of non-revenue water collected by the sewerage;
- Discharges of wastewater into the river Vardar in the central part of the city;
- Overload of wastewater sewers and outpouring of wastewater to the streets during rains, due to insufficient development of the stormwater network;
- Existence of illegal connections to the wastewater sewers;
- Existence of illegal discharges to the watercourses;
- Clogging at numerous locations in the network (based on sections inspected by CCTV);
- Existence of damaged sections in the network (based on sections inspected by CCTV);
- More than 20% of the network is older than 50 years.

3.5.4 Proposed measures for the wastewater collection system's upgrade

Upgrading of the existing wastewater collection system shall contribute to the following:

- improved hygienic standards for the population;
- fewer problems in the maintenance of the collection system;
- protection of the watercourse;
- proper functioning of the future Central WWTP.

In order to achieve such goals, the following measures were proposed as a priority:

- to develop design documentation and construct the main trunk sewer on the left bank and on the right bank of the river Vardar, from the existing discharge points of sewers to the location of planned Central WWTP in Trubarevo;

In addition to the stated measures, the following medium-term and long-term measures are proposed:

- to prepare a long-term plan for detail geodetic and CCTV survey of the whole existing wastewater network and carry out the gradual replacement of old pipes;
- to perform flow and quality measurement campaign of wastewater discharged from the sewer system (both separate and combined sub-system) in the period of one year;
- to replace/reconstruct the sewers identified for replacement by developed hydraulic model;
- to construct planned Central WWTP in Trubarevo;

- to prepare a Non-Revenue Water Reduction Study (supported by Hydraulic model of water supply system) based on a detailed leak detection campaign:
- to establish the control system of water abstraction from the wells located within industrial zones;
- to finish the following on-going wastewater projects:

3.5.5 Investigation works

For the needs of the development of the Feasibility Study and Cost-Benefit Analysis for Improvement of the Wastewater Collection Infrastructure in the City of Skopje, the Consultant executed the following investigation works:

- Analyzed Documentation and Data
- Demographic analysis
- Geodetic Survey of the pipelines
- Geotechnical Study. Geotechnical investigations along the main trunks' alignment
- Hydrological Data, mainly regarding the intensity of the rainfalls in for the City of Skopje
- CCTV inspection (camera recording of the pipeline insides)

3.5.6 Design data and Design parameters

After data has been collected and analysed, the next step of the development of the technical documentation is to set the design data and parameters. The following data have been determined prior to the design activities:

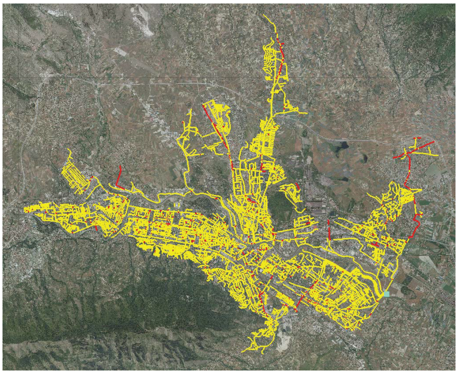
- Wastewater flows, which are determined based on the measures data from the Public Utility Company or in case those are not existing, conducting the wastewater measurement campaigns on the strategic locations of the wastewater collection system
- Design standards
- Hydraulic parameters: sewer capacity, maximum and minimum velocities, minimum and maximum pipe burring depth

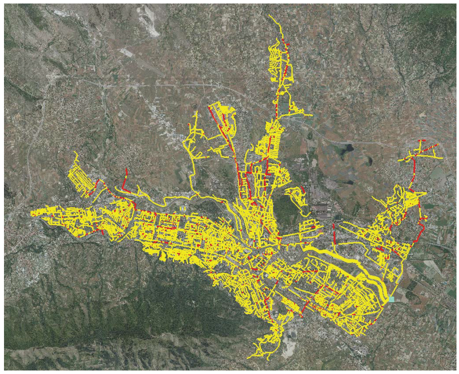
3.5.7 Hydraulic modelling of the wastewater collection network

By the use of the mathematical models, there is a possibility to better assess the existing and future conditions of the wastewater collection system, under various operating conditions. The modelling and simulations were performed by the use of specialized software, in this case, Canalis – Hydro system software package. It is software for planning and design of the sewerage systems. The software is embedded in an AutoCAD and AutoCAD MAP environment on Windows operating system.

Calculating the wastewater flow into the software is done by implemented algorithms for assigningcatchment areas. The wastewater flows are calculated using catchment areas and assigned population density or using the participation of pipe length of the entire network. The hydraulic calculation is based on the defined slopes and flows and sewers in the network are sized.

Analysis of the existing sewers reviled the hydraulic problems in the network for the dry and wet weather conditions, when hydraulic conditions are much different. An example of the modelling results is shown in the following drawings.

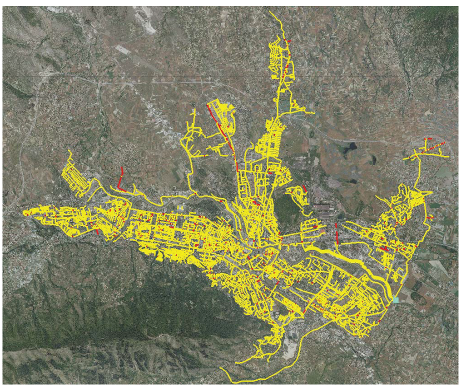


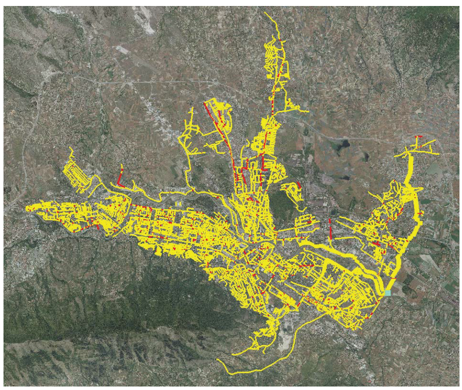


a.) *b.)*

Figure 3-27 Overloaded sewers in the existing wastewater network a) during dry periods, b) during wet weather periods

Theoretical modelling was also applied to the collection network after appalling the proposed modifications and extensions, as shown in the following figures





a.) *b.)*

Figure 3-28 Overloaded sections at the end of the design period, the year 2044 a) for dry conditions, b) for wet conditions

3.5.8 Technical solution for wastewater collection system

In general, technical solutions for wastewater system upgrading comprise mandatory/ priority solutions (Phase 1) and solutions for the future upgrading (Phases 2, 3 and 4).

- Section 1 - Construction of trunk sewer on the right bank of the river Vardar;
- Section 2 - Construction of trunk sewer on the left bank of the river Vardar;
- Section 3 - Construction of trunk sewer from the pumping station "Makosped" to the connection to the new main trunk sewer on the left bank of the River Vardar.

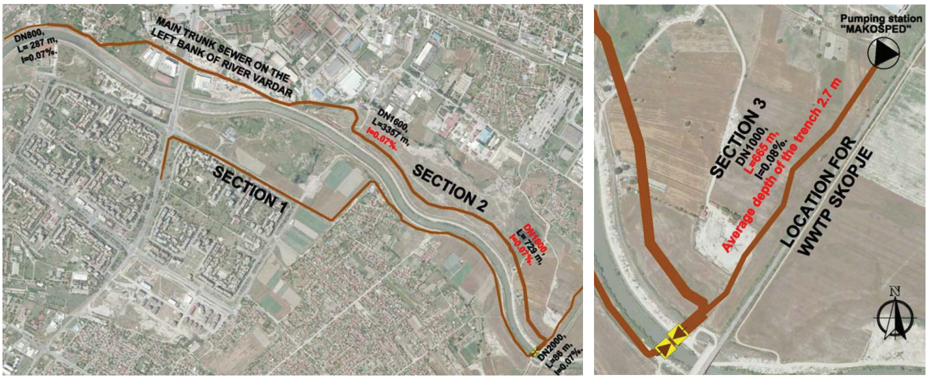


Figure 3-29 a) Sections 1 and 2 Trunk sewers on both river banks b) Section 3 Connection of the PS Makosped to the new main trunk sewer

Solutions for the future upgrading (Phases 2, 3, and 4) are divided into four sections, as follows:

Phase 2 – Construction of:

- Section 4 - Passage of trunk sewer beneath the Vardar River
- Section 5 – Connection to WWTP

Phases 3 and 4:

- Section 6– Reconstruction / Construction of sewers in the City of Skopje - Phase 3
- Section 7 – Reconstruction / Construction of sewers in the City of Skopje - Phase 4

During the year 2015 Detailed designs were prepared for the measures proposed under Sections 1, 2, and 3. The construction of these main trunks is ongoing.

3.5.9 Proposed measures for wastewater treatment

The urgent need for construction of WWTP in Skopje is justified due to urbanization, population growth, and rapid industrialization of the city of Skopje and local settlements, which will lead to larger amounts of untreated water from households and industry that will be discharged into the river Vardar.

As it was already explained above, four districts (in this case agglomerations) had been previously identified within the City of Skopje, as shown in Figure 3-24. The focus was on the development of technical documentation and construction of the central WWTP for the Centre district which will treat approximately 80% of the total population in the City of Skopje. As such construction and operation of this plan will have the highest impact on environmental protection and improving the quality of the Vardar river. The central WWTP will also receive the pre-treated wastewater from the major industries located in the agglomeration.

The wastewater treatment plant site is on the left bank of the Vardar River and to the eastern side of the City. It covers an area of 91 ha. Nevertheless, the construction site is expected to be much smaller leaving a space to be used for other purposes. Existing wastewater collection facilities consist of a scattered number of networks having each its own point of discharge into the Vardar River and its confluence. Main sewer trunks will be constructed on both river banks that will direct the collected wastewater flow to the projected WWTP. The priority measures related to the wastewater collection (construction of Section 1, 2, and 3) and construction of the central WWTP are presented in the Figure 3-30.

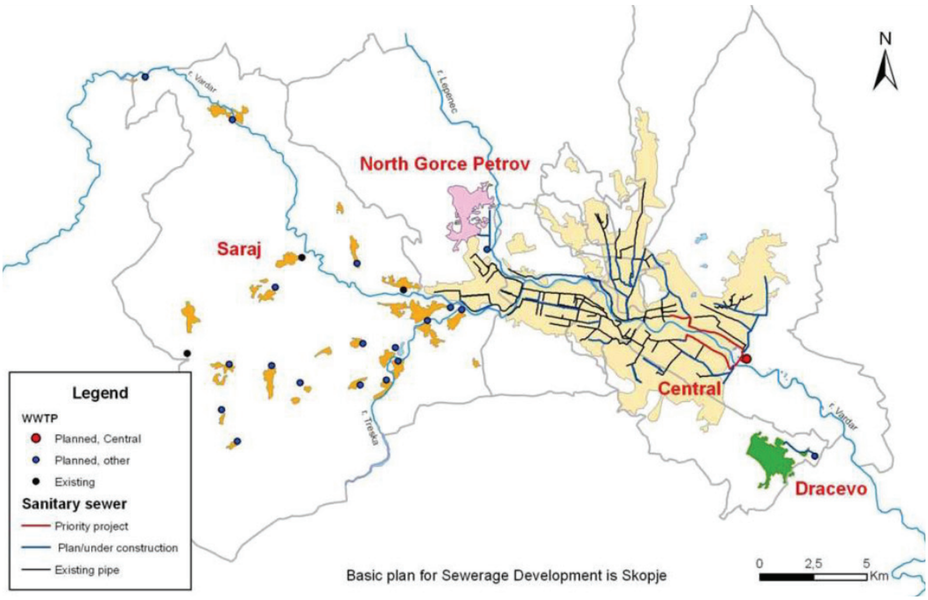


Figure 3-30 Priority measures for wastewater collection, and treatment

3.5.10 Investigation works

For the needs of the development of the Feasibility study for financing, construction and operation of WWTP for the City of Skopje, as well as the respective technical documentation, the following investigation works have been executed:

- **Collection and review of the existing spatial planning and technical documentation,** previous studies, design reports, as well as other information relevant for the project implementation;
- **Definition of the agglomeration.**
- **Demographic analysis** resulting in population forecasts until the end of the design period, which is 2040,
- **Industrial activities** in the agglomeration. Preparation of the database of the industries including their main characteristics related to wastewater generation and pre-treatment;
- **Wastewater quantity and quality measurement** needed to estimate the wastewater characteristics (BOD5, COD, TSS, TN, TP) and typical flows for dry and weather conditions, needed for the design purposes.

3.5.11 Design data and parameters

After data has been collected and analysed, the next step of the development of the technical documentation is to set the design data and parameters. The following data have been determined prior to the design activities:

- **Demand analysis.** To prepare projections for sanitary wastewater collection and treatment system (demographic changes, population coverage, domestic and non-domestic wastewater flows and loads, ...). To prepare projections for stormwater collection system (demographic changes, population coverage, stormwater flows, ...). The analysis resulted with projections of the Population Equivalent (PE);
- **Effluent requirements,** in accordance with the national and EU legislation;

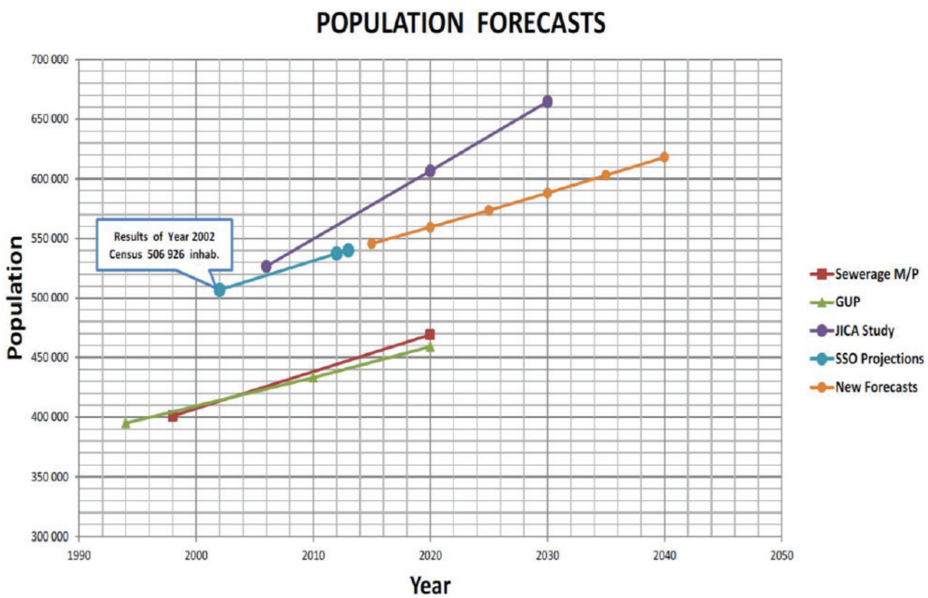


Figure 3-31 Population forecasts

Summarizing the above analysis, resulted in the estimation of the wastewater quantity and quality at the entrance of the WWTP for the characteristic years of the design period. The summarised information for the dry and wet weather periods are presented in Table 3-10.

The conclusion of the Feasibility study for this project is that the development of the WWTP will be conducted in two phases:

» Phase I with design horizon until the year 2030. The capacity of the plant will be 625,000 PE, with a secondary treatment level

» Phase II with design horizon until the year 2040. The plant will be extended to a total capacity of 650,000 PE, with a tertiary treatment level

Table 3-10 Influent and effluent summary

Parameter	Year 2030		Year 2040	
	Inflow / pollution load (kg/d)	Effluent quality (mg/l)	Inflow / pollution load	Effluent quality (mg/l)
Dry weather				
Daily flow	131,540 m^3/d		137,520 m^3/d	
Max. daily flow	2.53 m^3/s		2.67 m^3/s	
BOD5	34,200	25	35,100	25
TSS	42,500	35	43,500	35
COD	71,200	125	72,800	125
N	5,900	40	6,100	40
TP	1,000	5	1,000	5
Wet weather				
Daily flow	162,540 m3/d		168,520 m3/d	
Max. daily flow	2.89 m3/s		3.02 m3/s	
BOD_5	37,600	25	38,500	25
TSS	54,900	35	55,900	35
COD	83,600	125	85,200	125
N	6,300	10	6,500	10
TP	1,000	1	1,000	1

3.5.12 WWTP site location

Construction of WWTP with a capacity 600,000 PE requires a significant construction area. These days it is difficult to obtain adequate construction area, even for the state authorities.

The selected location for the construction of the WWTP is in village Trubarevo, on the left bank of river Vardar. The plot has an area of 91 ha, which is sufficient for the construction of this size of the plant.

Even if this site is with enough size, there are constraints that have to be taken into account during the design and construction of the plant:

» The site is prone to flooding
» Possible high level of underground water in wet weather conditions
» Electricity and gas infrastructure present on the site, which has to be relocated
» The access road is not yet constructed

These and some other constraints have to be carefully analyzed before making a decision on the site selection. In Skopje's case, the site has been pre-selected already, so the project has to be adjusted to the site. Sometimes these adjustments tend to increase the construction cost significantly. Therefore, spending some time analyzing multiple site options may save investment funds.

3.5.13 Wastewater treatment plant option analysis

After setting the design parameters, the next step is the analysis of several options for wastewater and sludge treatment.

The assessment aims to define, analyze, and compare the possible solutions for municipal wastewater treatment and disposal/reuse/elimination of sludge, in order to confirm the correctness of the solution that will be recommended. Taking into account the requirements of the project in terms of sustainable development, an assessment was made of the options for generating electricity and heat for wastewater treatment processes, as well as control of gas emissions and treatment.

The process of evaluating possible solutions includes the following steps:

i. Presentation of the proposed basic design data, which among other things include data on the flow and load to be introduced into the future plant, the target value of the treated effluent, design limiting factors, and various other specific requirements.

ii. Selection of possible options for wastewater treatment and preliminary assessment that covers the objectives of the project and the limitations for the application of some of the options;

iii. Presentation of issues related to disposal / conditioning / reuse / elimination of sludge, including energy recovery options;

iv. The conceptual design of the selected treatment solutions will consist of a general description of the planned works, including process diagrams and preliminary sizing of the proposed wastewater and sludge treatment plants;

v. Calculation of costs for each envisaged option, i.e. estimation of capital and operating costs;

vi. Comparison of options based on different technical and financial criteria and recommendations for selecting the best options/solutions.

There are various existing well-proved processes that enable the treatment of BOD_5, COD, and TSS and their removal from the wastewater as per the effluent requirements. Because these processes are numerous and often differ from each other in their characteristics, primarily in terms of complexity of land and equipment, it is necessary to first select the most recommended processes taking into account the specifics of the project.

Therefore, for the preliminary analysis it is proposed to adopt the following basic criteria:

» Available land requirements;
» Appropriateness of the process in relation to the required level of treatment in terms of achieving the short-term, medium-term and long-term goals of the project;
» Impact on the environment;
» Raw water characteristics of the influent entering the WWTP;
» Existing application for similar treatment facilities in the country and the region;
» Sludge production.

The following table shows the basic characteristics of each wastewater treatment process:

Table 3-11 Basic process characteristics

Process	Pre-treatment	Primary sedimentation	Biological tank	Secondary sedimentation	Sludge extraction and treatment		Treatment efficiency (mg/l) (%)				
					Primary sludge	WAS	BOD_5	COD	TSS	TN	TP
BF	x	x	x ff	-	x	x	15 95	10 95	50 90	10 85	1 85
AL	x	-	x sg	-	-	x	20 95	90 80	30 90	10 80	3 50
CAS	x	x	x sg	x	x	x	20 95	90 80	30 90	5 90	1 80
EA	x	-	x sg	x	-	x	20 95	90 80	30 90	5 90	1 80
MBR	x	option	x sg	-	option	x	10 98	50 90	5 95	5 90	1 80
SBR	x	option	x sg	-	option	x	20 90	90 80	30 90	5 90	1 80
TF	x	x	x ff	x	x	x	30 80	135 70	60 80	40 20	4.8 20
MBBR	x	x	x sg & ff	x	x	x	20 95	90 80	30 90	5 90	1 80

where: BF – Biological filtration; AL = aerated lagoon; CAS = conventional activated sludge process; EA = extended aeration; MBR = membrane biological reactor; SBR = sequential Batch Reactor, TF = trickling filter, MBBR = mixed bed biological reactor. Sg – suspended growth, ff – fixed film

The assessment of the different processes according to the selected criteria is given in the following table.

Table 3-12 Analysis of the treatment technologies against specific requirements

Process	Land availability	Required level of treatment	Environmental impact	Influent characteristics	application for similar treatment
BF	Compatible with the size of the location	Applicable for any treatment level		Compatible with the influent characteristics	Could be used for any size of the plant
AL	Non-compatible with the size of the location	Difficult to achieve BOD, COD reduction. Impossible to achieve N and P reduction		Compatible with the influent characteristics	Not used for large size of plants
CAS	Compatible with the size of the location	Applicable for any treatment level		Compatible with the influent characteristics	Most frequently used process for any size of the plant
EAS	Compatible with the size of the location	Applicable for any treatment level	Bad odor is present particularly at the sludge treatment area	Compatible with the influent characteristics	Most frequently used process for any size of the plant
MBR	Compatible with the size of the location	Applicable for any treatment level		Compatible with the influent characteristics	Most frequently used process for any size of the plant
SBR	Compatible with the size of the location	Applicable for any treatment level		Not recommended for highly diluted influent as in this case	Usually used for small and medium size of plants
MBBR	Compatible with the size of the location	Applicable for any treatment level		Compatible with the influent characteristics	Usually used for upgrading of the existing WWTP. Not suitable for new large size plants
TF	Compatible with the size of the location	Difficult to achieve BOD, COD reduction.	Mild odor. Attracts mosquitos and birds	Compatible with the influent characteristics	Low level of use due to the low efficiency

As can be seen, certain processes have characteristics that are not appropriate or ideal compared to the needs, limitations, and requirements of the project.

Therefore, it was proposed to exclude inappropriate processes from further analysis. The processes that are excluded from further analysis are the following:

» Sequential Batch Reactor (SBR) process is a very efficient process; but it is most often used for the treatment of highly concentrated wastewater, which is not the case with the City of Skopje, where the high level of infiltration in the sewerage system increases the dilution of the wastewater flow.
» The Movable Biofilm Cover (MBBR) reactor process is also a highly efficient process. However, it is most commonly used to upgrade the capacity and/or efficiency of small and medium WWTPs. Not used in the construction of new large stations.
» The process with aerated lagoons (AL) is not suitable for this project considering the size of the location envisaged for construction, i.e. for this system a location with over 150 ha should be provided for the Central WWTP), and at the same time, this process does not achieve the prescribed effluent quality requirements.
» The conventional trickling filtration process is not an appropriate solution given the low efficiency in achieving the prescribed effluent quality requirements.

As a conclusion of the above analysis, four possible wastewater treatment options have been further analysed, and for each of these technologies, there are five different sludge treatment options.

Table 3-13 Selected wastewater and sludge treatment options

Wastewater treatment	Sludge treatment
Option 1: Extended aeration (EAS) Option 2: Activated sludge with primary sedimentation (ASPS) or conventional process with activated sludge (CASP) Option 3: Membrane reactor (MBR) Option 4: Biological filtration (BF)	For each WW technology: • Option a: thermal drying • Option b: Incineration • Option c: lime treatment • Option d: thermal hydrolysis • Option d: thermal hydrolysis with thermal drying

Each of the treatment options had been developed up to the level of Conceptual design for two design horizons in terms of treatment quality and plant capacity, as shown in the previous chapters.

For each option, the Conceptual design included at least the following:

» Definition of the treatment line and summarizing it in a process diagram;
» Determining the number of main treatment reactors by showing their characteristics and size;
» Establishment of a conceptual layout of the various plants at the designated location.

The following figures and charts are giving an overview of the analysed technologies:

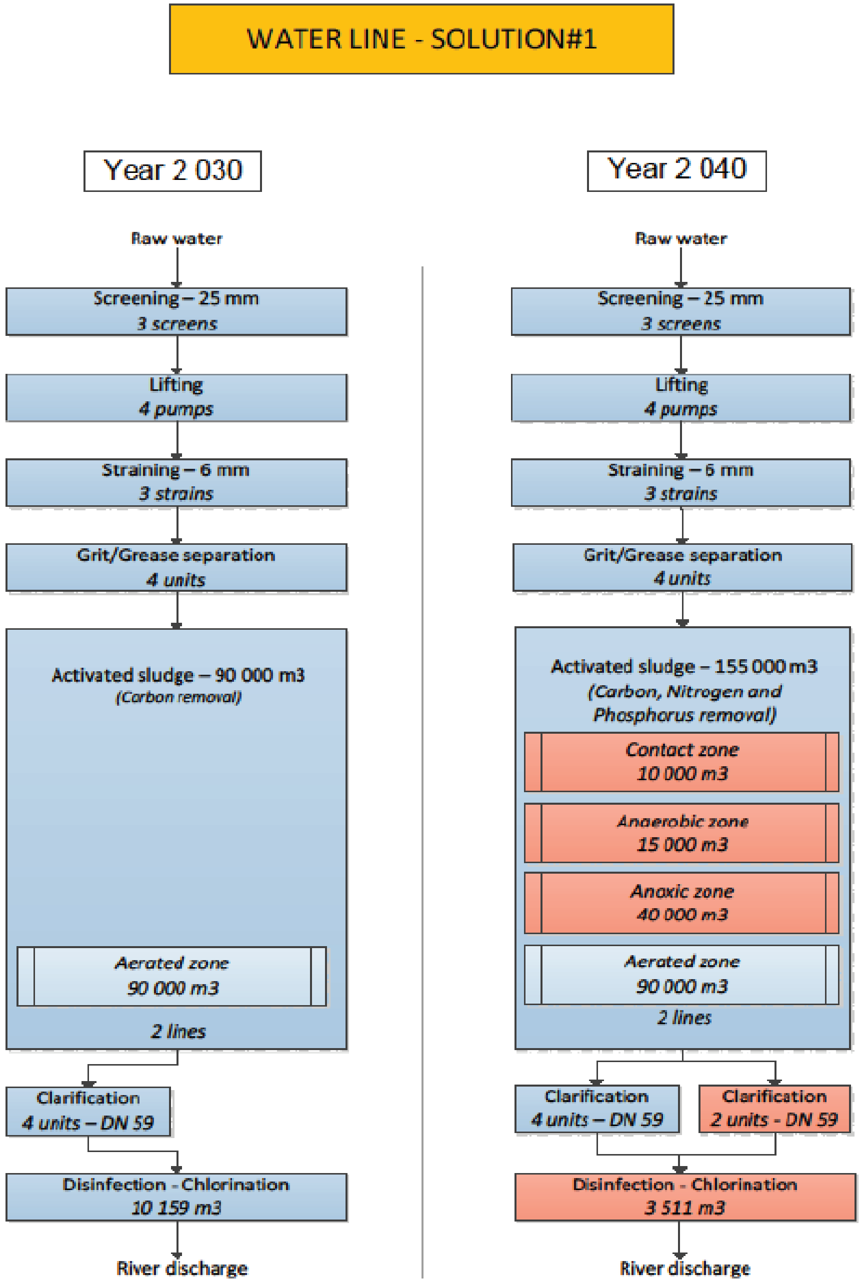


Figure 3-32 a) Option 1 – EAS

Figure 3-32 b) Option 2 - CAS

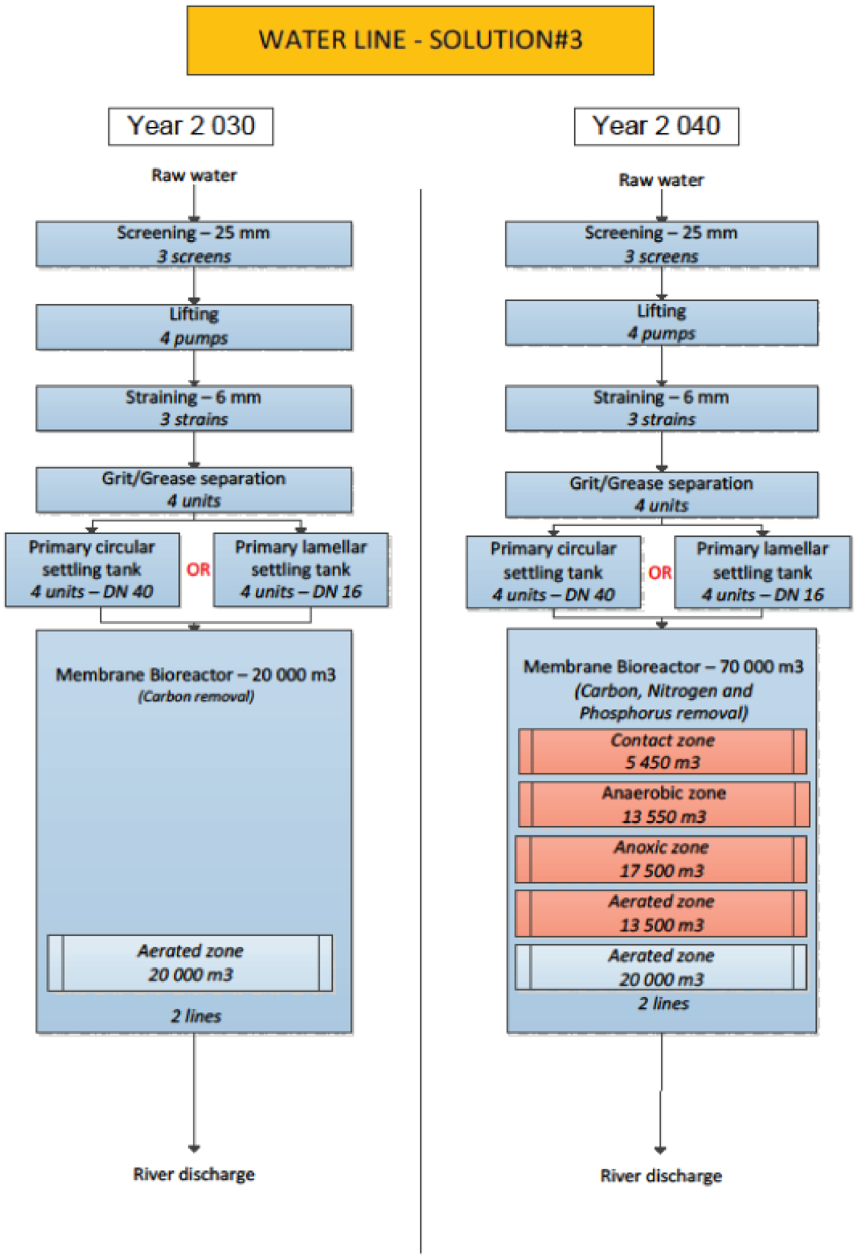


Figure 3-33 a) Option 1 – MBR

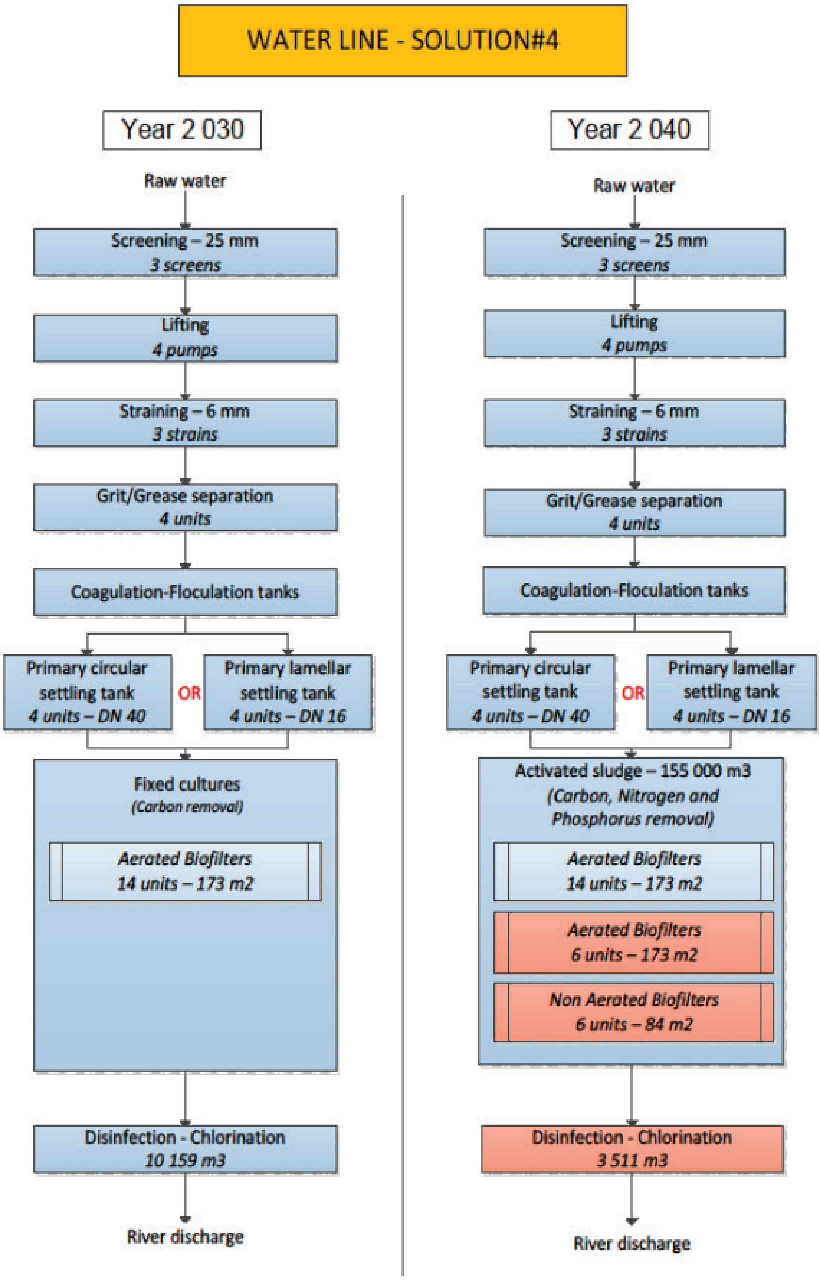
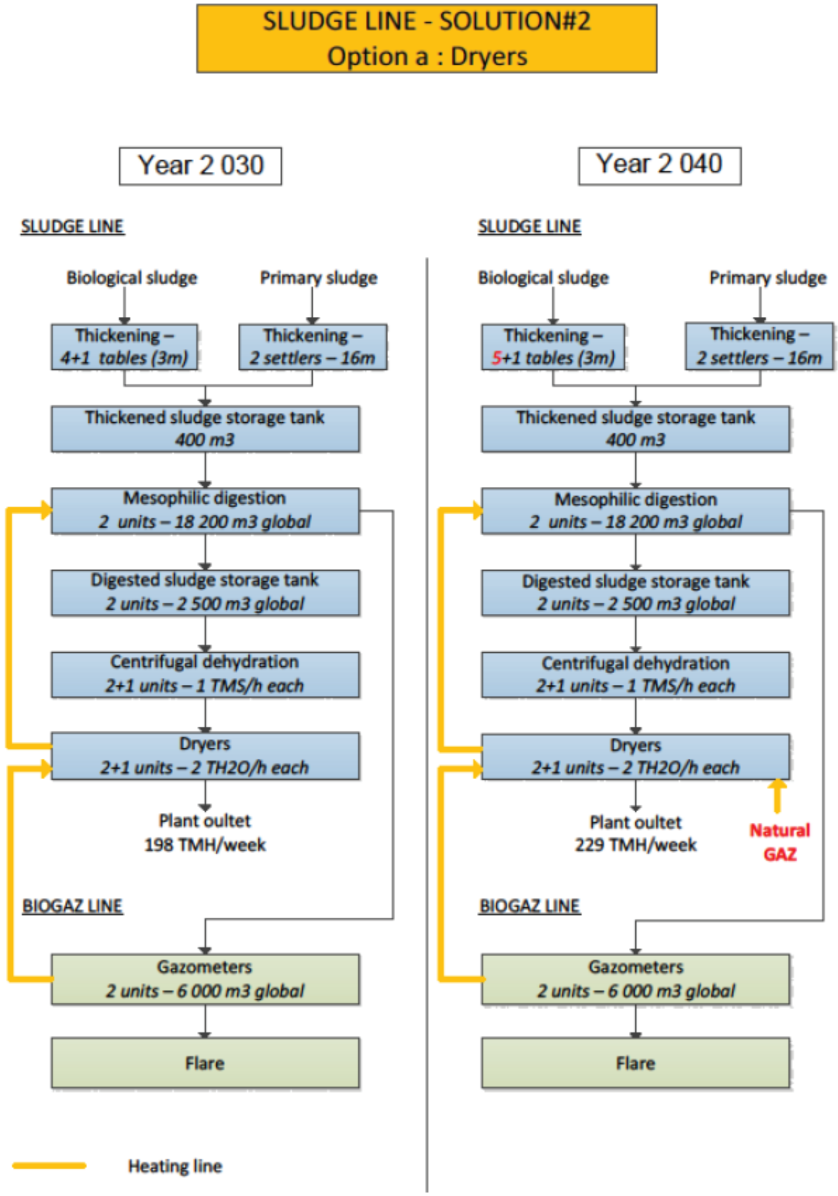
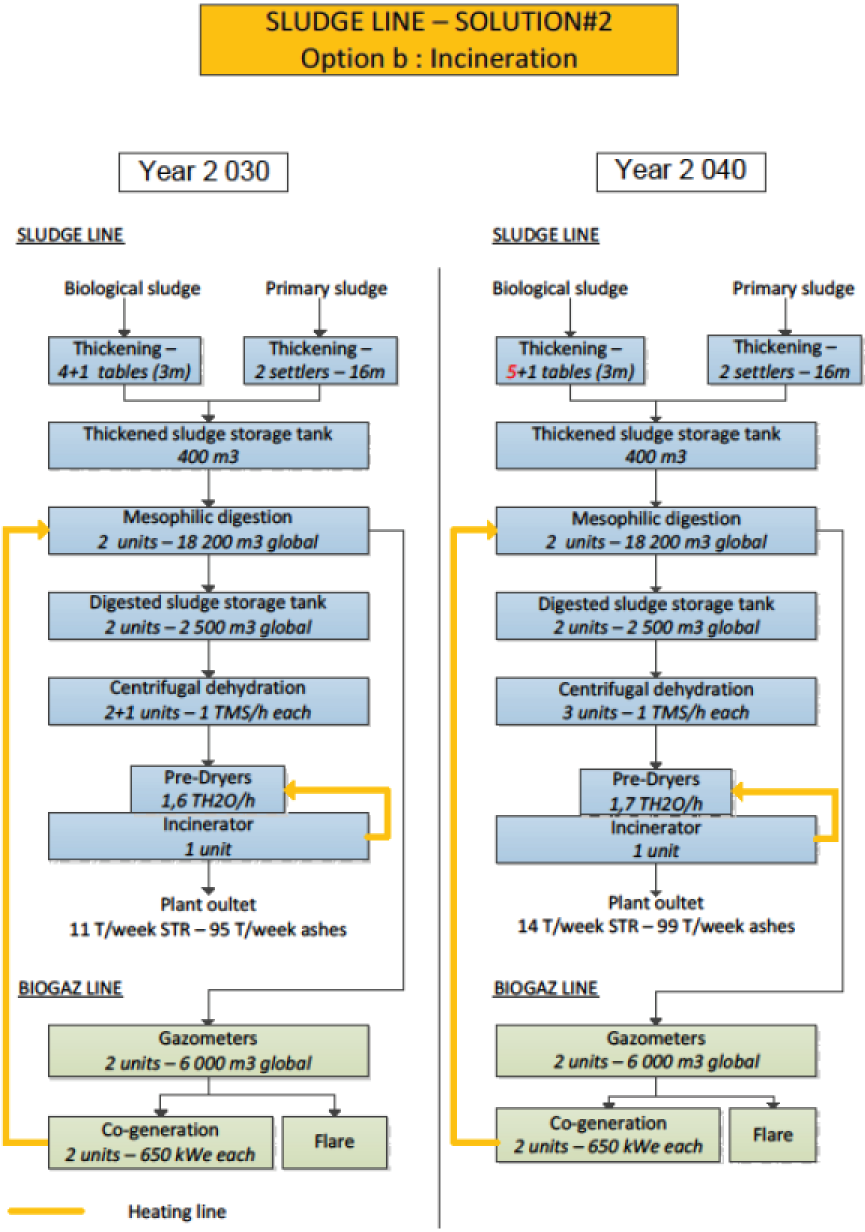
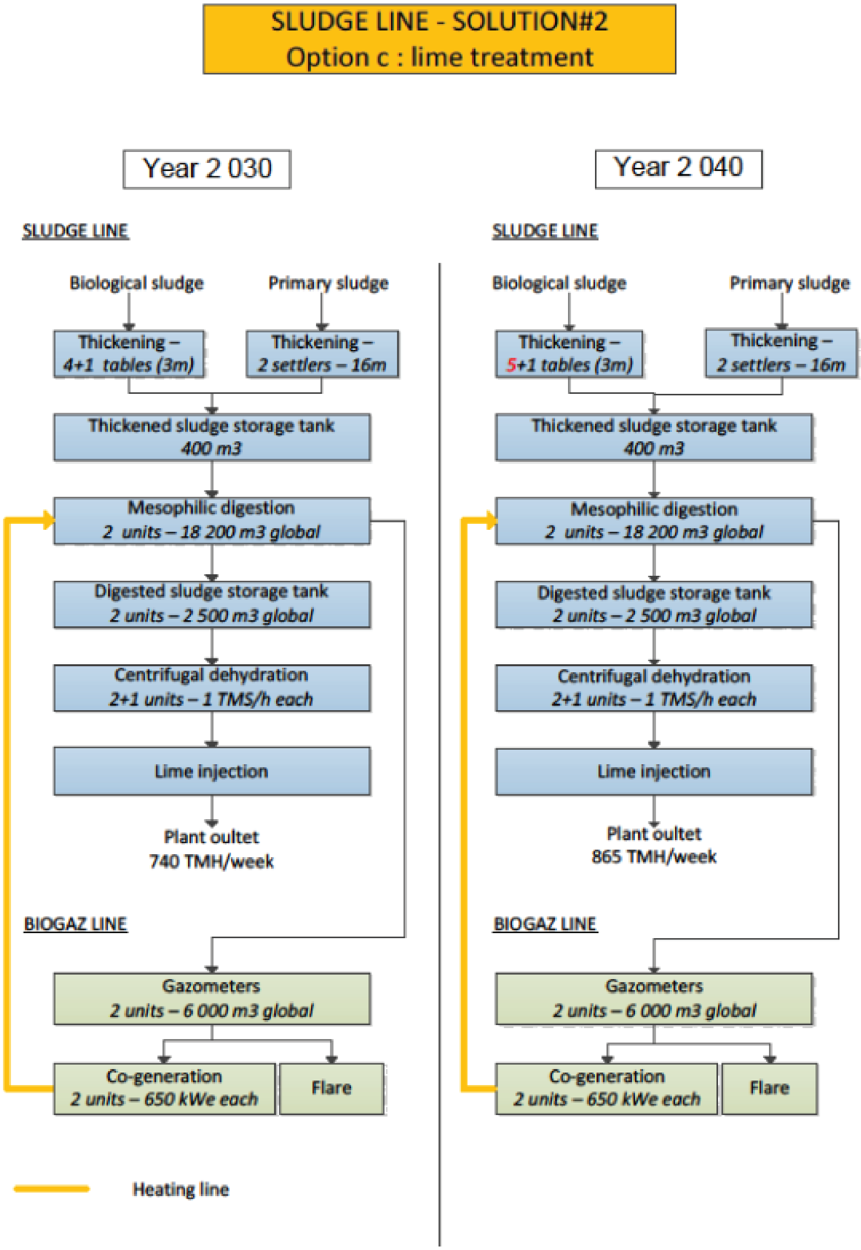


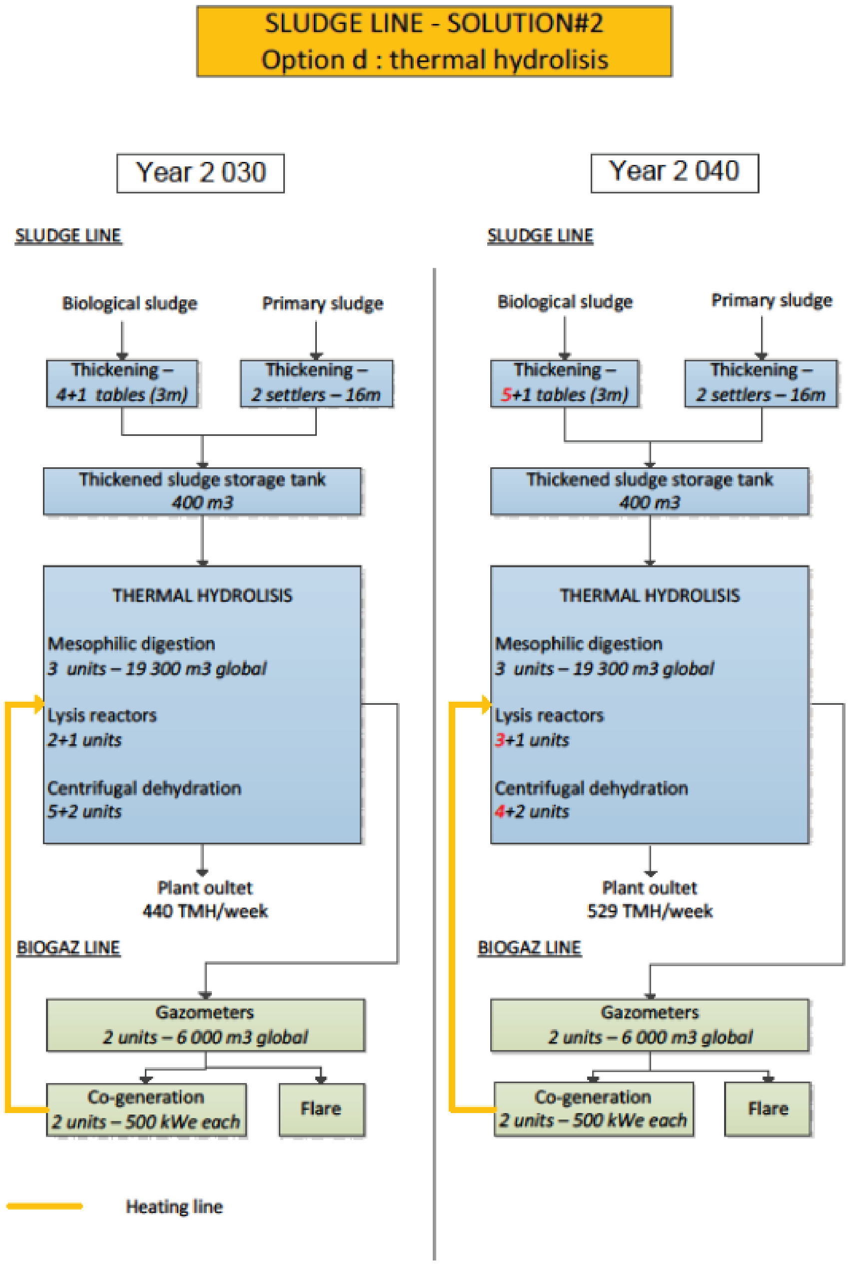
Figure 3-33 b) Option 2 - BF

As mentioned above, there have been 5 sludge treatment technologies analysed, shown in details on the organograms below:




SLUDGE LINE – SOLUTION#2
Option b : Incineration
Year 2 030
SLUDGE LINE
Biological sludge
Primary sludge
Thickening – 4+1 tables (3m)
Thickening – 2 settlers – 16m
Thickened sludge storage tank 400 m3
Mesophilic digestion 2 units – 18 200 m3 global
Digested sludge storage tank 2 units – 2 500 m3 global
Centrifugal dehydration 2+1 units – 1 TMS/h each
Pre-Dryers 1,6 TH2O/h
Incinerator 1 unit
Plant oultet
11 T/week STR – 95 T/week ashes
BIOGAZ LINE
Gazometers 2 units – 6 000 m3 global
Co-generation 2 units – 650 kWe each
Flare
Heating line
Year 2 040
SLUDGE LINE
Biological sludge
Primary sludge
Thickening – 5+1 tables (3m)
Thickening – 2 settlers – 16m
Thickened sludge storage tank 400 m3
Mesophilic digestion 2 units – 18 200 m3 global
Digested sludge storage tank 2 units – 2 500 m3 global
Centrifugal dehydration 3 units – 1 TMS/h each
Pre-Dryers 1,7 TH2O/h
Incinerator 1 unit
Plant oultet
14 T/week STR – 99 T/week ashes
BIOGAZ LINE
Gazometers 2 units – 6 000 m3 global
Co-generation 2 units – 650 kWe each
Flare


SLUDGE LINE - SOLUTION#2
Option c : lime treatment
Year 2 030
SLUDGE LINE
Biological sludge
Primary sludge
Thickening – 4+1 tables (3m)
Thickening – 2 settlers – 16m
Thickened sludge storage tank 400 m3
Mesophilic digestion 2 units – 18 200 m3 global
Digested sludge storage tank 2 units – 2 500 m3 global
Centrifugal dehydration 2+1 units – 1 TMS/h each
Lime injection
Plant oultet 740 TMH/week
BIOGAZ LINE
Gazometers 2 units – 6 000 m3 global
Co-generation 2 units – 650 kWe each
Flare
Heating line
Year 2 040
SLUDGE LINE
Biological sludge
Primary sludge
Thickening – 5+1 tables (3m)
Thickening – 2 settlers – 16m
Thickened sludge storage tank 400 m3
Mesophilic digestion 2 units – 18 200 m3 global
Digested sludge storage tank 2 units – 2 500 m3 global
Centrifugal dehydration 2+1 units – 1 TMS/h each
Lime injection
Plant oultet 865 TMH/week
BIOGAZ LINE
Gazometers 2 units – 6 000 m3 global
Co-generation 2 units – 650 kWe each
Flare


SLUDGE LINE - SOLUTION#2
Option d : thermal hydrolisis
Year 2 030
Year 2 040
SLUDGE LINE
Biological sludge
Primary sludge
Thickening – 4+1 tables (3m)
Thickening – 2 settlers – 16m
Thickened sludge storage tank 400 m3
THERMAL HYDROLISIS
Mesophilic digestion
3 units – 19 300 m3 global
Lysis reactors
2+1 units
Centrifugal dehydration
5+2 units
Plant oultet
440 TMH/week
BIOGAZ LINE
Gazometers
2 units – 6 000 m3 global
Co-generation
2 units – 500 kWe each
Flare
SLUDGE LINE
Biological sludge
Primary sludge
Thickening – 5+1 tables (3m)
Thickening – 2 settlers – 16m
Thickened sludge storage tank 400 m3
THERMAL HYDROLISIS
Mesophilic digestion
3 units – 19 300 m3 global
Lysis reactors
3+1 units
Centrifugal dehydration
4+2 units
Plant oultet
529 TMH/week
BIOGAZ LINE
Gazometers
2 units – 6 000 m3 global
Co-generation
2 units – 500 kWe each
Flare
Heating line

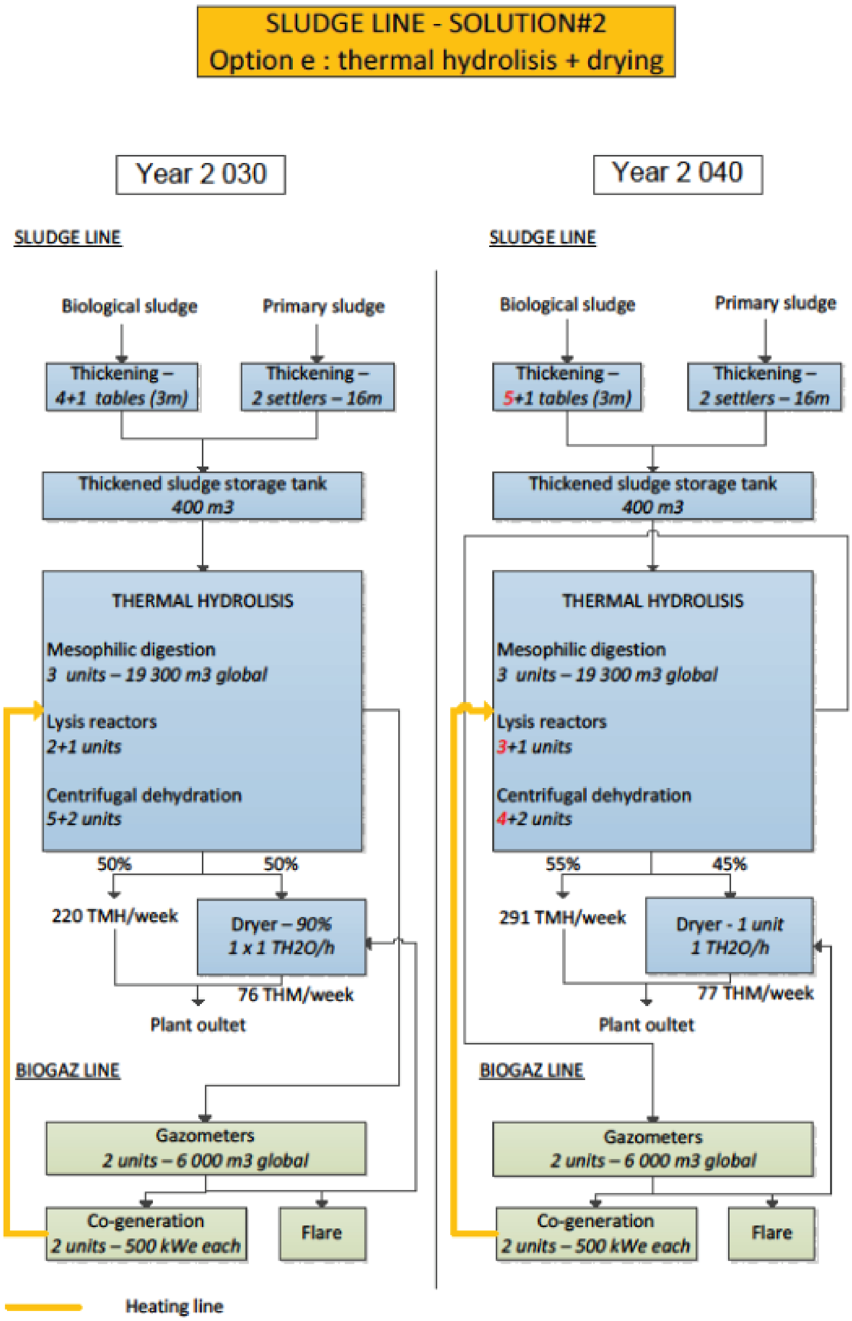


Figure 3-34 Sludge treatment technologies

In order to choose the most appropriate technology, both the capital expenditures and the operating expenses have been estimated, and both techno–economic and SWOT analysis have been made. The results have shown that the Option 2 - Conventional Activated Sludge Process with a capacity of 625,000 PE with secondary treatment level up to 2030 and with a capacity of 650,000 PE and tertiary treatment level up to 2040 is the most suitable one.

Regarding sludge treatment options, the Feasibility study is not giving a straightforward recommendation, but rather is keeping the multiple options open. In the meantime, North Macedonia has prepared and adopted a national sludge management strategy, which is proposing the dried sludge incineration with co-generation as the most appropriate technology at the national level.

The layout of the selected treatment option is presented in the following figure.

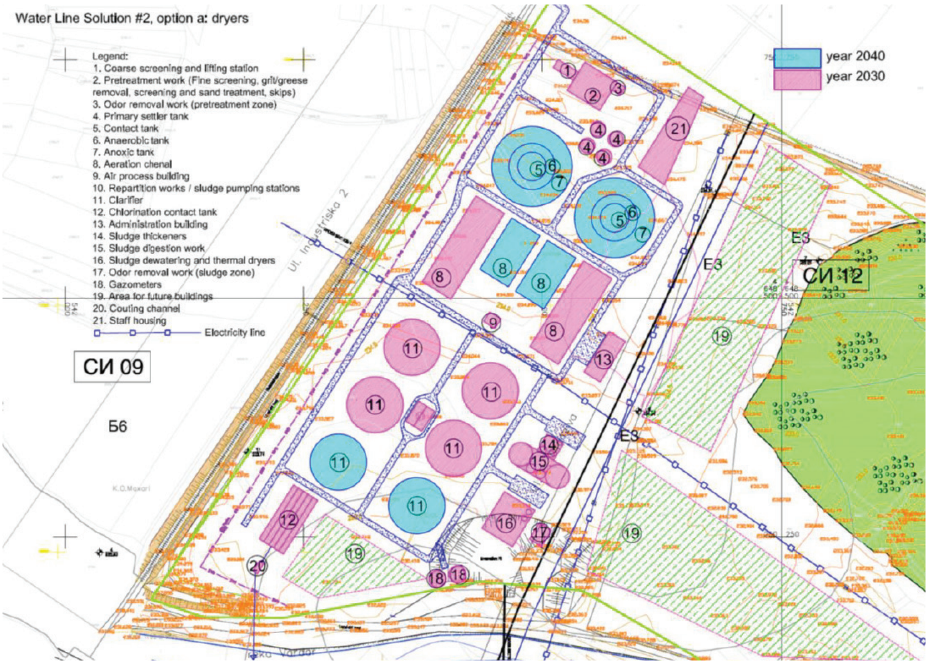


Figure 3-35 Layout of the Option 2: Conventional activated sludge treatment

3.5.14 Environmental and social benefits and risks

The key benefits of the Project are the following:

» Stopping the current practice of discharging untreated wastewater into the Vardar River.
» Expansion of the wastewater collection and installation of a comprehensive wastewater treatment system in the city of Skopje, which will improve the environment protection and the health of the population in the city of Skopje and the areas along the river. More than 500,000 inhabitants of the city of Skopje (almost 1/3 of the total population in North Macedonia) will benefit from better wastewater management, as well as all inhabitants of the settlements along the river in North Macedonia and Greece, until the Aegean Sea.
» Fulfilling the strategic goals set out in the state-level water management strategies and plans and meeting the provisions of local legislation in order for the intruders to achieve "good status" and prevent further deterioration of the existing surface and groundwater status.
» Greater employment opportunities for the local population during the construction and operation of the WWTP.

The key risks of the Project are the following:

» In case of malfunction and improper functioning of the WWTP, concentrated wastewater can be discharged from the WWTP into the river Vardar, which in turn could be fatal for the water world in the river and generally have a negative impact on settlements along the stream.
» Leaving an unpleasant odour in case of malfunction or improper functioning of the odor treatment system and improper treatment of sludge could harm the local population in the settlements northwest, southeast, and southwest of the WWTP.
» Malfunction of the combustion plant filters may cause air emissions above the permissible values, which may affect the population living in the nearest settlements on the WWTP site.
» Accidents, such as explosions or fires, that could affect the balance of fauna species in the surrounding areas, including the Ostrovo Protected Area.

3.5.15 Institutional setup for water supply and wastewater services

Institutional actors involved in water supply and wastewater management for Skopje City as well as their responsibilities and prerogatives with regard to the wastewater sector is as listed below:

I. The Ministry of Transport & Communications (MTC), which is involved in the following issues:

   a. Regulation on sewage;
   b. Assistance in sewerage projects development and implementation;
   c. Monitoring the Water & Sewerage Board of Skopje (Vodovod I Kanalizacija);
   d. Laws on water;
   e. Collection & treatment of sewage flow;
   f. Sewage tariff guidelines;

II. The Ministry of Environment and Physical Planning (MoEPP) its main involvement as far as water and wastewater issues cover the following:

   a. Law on Environment;
   b. Environmental Impact Assessment (EIA) regulations;
   c. Industrial wastewater monitoring (Class A: industries with large quantities of dangerous substances related to noise generation and water and air pollution);
   d. Wastewater monitoring;
   e. Law propositions on waters;
   f. Water management;
   g. Spatial Planning;

III. Ministry of Agriculture, Forestry, and Water Economy (MAFWE) is in charge of:

   a. The law on water;
   b. Regulation on water quantity and quality to be discharged into the receiving water body;
   c. Monitoring river flow quality;

IV. The City of Skopje, as a local authority and beneficiary of sanitation projects within the City boundary, is in charge of:

   a. Planning, design, and implementation of sewage facilities;
   b. Control of the water and sewage board (Vodovod i Kanalizacija) of the city;

V. Sewerage Board of Skopje or Vodovod i Kanalizacija is in charge of:

   a. Approval of the revision of sewerage service tariffs;
   b. Monitoring of Industrial wastewater flow (Class B: Same as Class "A" industries but smaller quantities of pollutants)

3.6 Wastewater treatment in Greece

The objective of the Urban Waste Water Treatment Directive, Directive 91/271/EEC, as amended by the Directive 98/15/EU, is to protect the environment from the adverse effects of urban wastewater discharges and discharges from certain industrial sectors (see Annex III of the Directive) and concerns the collection, treatment and discharge of domestic wastewater, a mixture of wastewater and wastewater from certain industrial sectors. The Directive has been integrated into national legislation with the JMD 5673/400/1997 (Official Government Gazette 192B/14-3-1997) titled “Measures and terms on the treatment of urban wastewater”. The designation of sensitive areas was initially performed in 1999 (JMD 19661/1982/1999 – Official Government Gazette 1811B/29-9-1999) and was updated in 2002 (JMD 48392/939/3-2-2002 – Official Government Gazette 405B/3-4-2002). The agglomerations with a population equivalent greater than 2,000 inhabitants, fall under the provisions of the Directive.

The National Database of the Urban Waste Water Treatment Plants (UWWTPs) has been designed and developed by the Special Secretariat for Water, in the framework of the requirements of the Directive 91/271/EEC, having the objective of the immediate and continuous monitoring of the implementation progress of the Directive in Greece, as well as the direct information of the public. The National Data Base is operational since 2012 and constitutes an important interactive tool, which is being used on a daily basis by the Special Secretariat for Water, responsible for the operation of the infrastructure authorities and the public. The National Database, with the initiative and the support of the European Commission Directorate-General for Regional and Urban Policy, has been upgraded and enriched, presenting all UWWTPs and the agglomerations, whilst its upgraded version provides the capability of presenting the information that it contains in an advanced geographical environment.

Within the Database technical and operational data of the UWWTPs in Greece, information on the means of disposal or reuse of wastewater and sludge, as well as the Environmental Terms of each UWWTP are stored and are publicly available (Fig. 1-2). The competent authorities and the authorized users are responsible for the reporting of the information and the operational data, while the latter is being evaluated by the Special Secretariat for Water, which provides directions, instructions, and support to all users. The compliance status of the UWWTPs is determined based on the requirements of the legislation and the prescribed for this purpose algorithm.

The Special Secretariat for Water as the national competent authority for implementing the Directive 91/271/EEC, and specifically the requirements of the articles 15 and 17, submits every two years to the European Commission, the Implementation Report and the National Implementation Programme, which contain all the required data relevant to the collection, treatment and disposal of the wastewater in Greece.

For a complete monitoring system, the Ministry of Environment and Energy (ypeka.gr) in Greece, has implemented interactive maps that demonstrate the locations of all WWTPs in the country (Figure 3-36). The map (updated 2018) is providing information on

- The Authority that runs the WWTP, the funding program, the date of construction, the date of operation, and the Environmental Terms expiration date
- Agglomerations served by the WWTP via sewage network
- Sewage from the agglomerations that is carried to the WWTP by trucks
- Whether the WWTP receives industrial wastewater or not
- Incoming loads (kg BOD5/d)
- Incoming flow (m3/d)
- The stages of wastewater and sludge treatment applied
- The water body receiver, and whether it is sensitive or not
- Reuse of the treated outflow
- Sludge disposal and/or reuse
- The compliance of the WWTP with the criteria set by Directive 91/271/EEC and JMD 5673/400/1997
- Sampling results

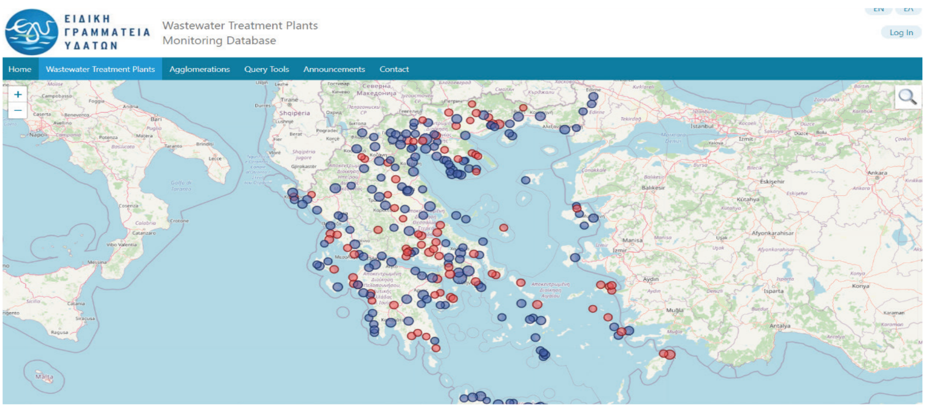


Figure 3-36 Wastewater treatment plants monitoring database in Greece[12]

12 Source: www.astikalimata.ypeka.gr/Services/Pages/WtpViewApp.aspx

In this map (Figure 3-36), blue circles indicate WWTPs compliant with the requirements of the Directive 91/271/EEC (UWWTD). Red circles indicate WWTPs that are not compliant with the UWWTD, either because they do not collect a sufficient number of samples per year, or because the effluent is not within the limits set by the UWWTD. In Figure 3-37, green circles indicate agglomerations compliant with the UWWTD, i.e. connected with a collecting system (connection rate >98%) and served by a WWTP. Orange circles indicate agglomerations not compliant with the UWWTD, i.e. not served by a collecting system or the connection rate is less than 98% or the UWWTP is not compliant with the requirements of UWWTD. The size of the dot is logarithmically related to the capacity of the WWTPs and the population equivalent for the agglomerations.

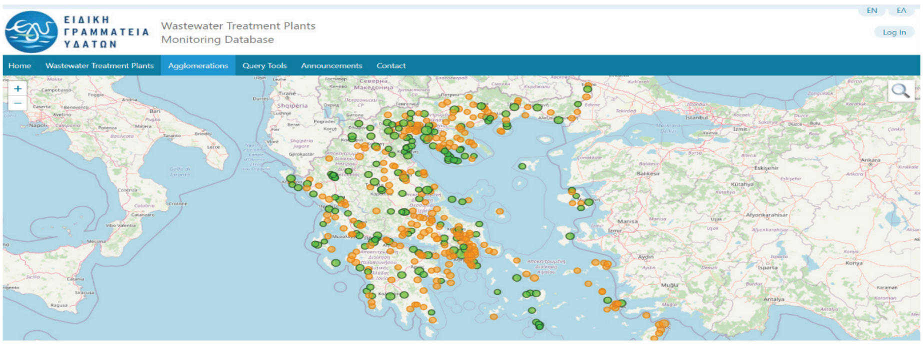


Figure 3-37 Agglomerations served by the WWTPs via sewage network in Greece[13]

The European Commission publishes every two years the summary on the Implementation of the Urban Waste Water Treatment Directive in the Member States. The most recent Report that has been published refers to the year 2014, Ninth Report on the implementation status and the programs for implementation of Council Directive 91/271/EEC concerning urban wastewater treatment. According to this latest Report, after more than 25 years following the adoption of the Directive, significant progress has been achieved towards full implementation. This has led to a gradual yet important improvement as far as the quality of the European waters is concerned. However, despite the generally high implementation level of the Directive, a number of challenges remain, such as:

- Investing further in the wastewater sector to increase or maintain implementation.
- Improving the quality and recovery of sludge.
- Reducing the effects of stormwater overflows polluting water bodies with untreated wastewater.

13 Source: http://astikalimata.ypeka.gr/Services/Pages/AgViewApp.aspx

- Increasing the reuse of treated wastewater while ensuring the appropriate water quality. The European Commission has submitted an institutional framework proposal on the reuse of urban wastewater.
- Optimizing the energy consumption of treatment plants.
- Ensuring the affordability of wastewater services in the knowledge that the needs for investments in the water sector are broader than only for collection and treatment, as they also include drinking water, protection against floods, and water availability in some regions.

3.7 Case study – Thessaloniki

Vardar river flows into the North Aegean Sea as Axios river in Greece (87 km long, extending over 3,212 km²) and covers 23,747 km² (86.9%) of North Macedonia[14]. Axios is also one of the most important transboundary rivers in Greece, mainly because of the use of water for irrigation in the fertile plain of Thessaloniki. The river forms a very rich ecological delta (protected RAMSAR site) before discharging into Thermaikos bay. The city of Thessaloniki is located east of the lower river, as shown in Figure 3-38.

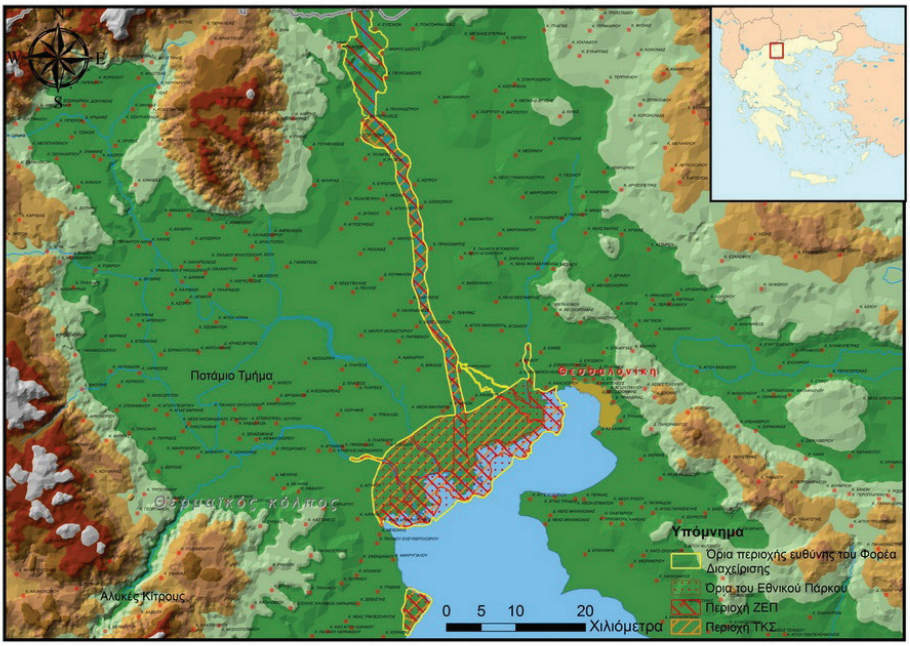


Figure 3-38 Protected delta area of the Axios river, in Greece

14 Source: www.inweb.gr

When the WWTP of Thessaloniki was designed in 2000, for its projected population of over 1 million, the initial plan for the disposal of treated sewage in the Axios river was rejected and completely modified to an alternative solution, in order to protect the river's water quality and the entire ecosystem. Thessaloniki's sewage is collected via combined systems in two separate WWTPs, as shown in Figure 3-39. The main WWTP, that serves most part of the municipality of Thessaloniki, is near the Axios and Gallikos rivers (on the west side of the city). The second, and much smaller WWTP, named Aeneas, is located on the eastern side of the city, and outfalls in the open Thermaikos gulf.

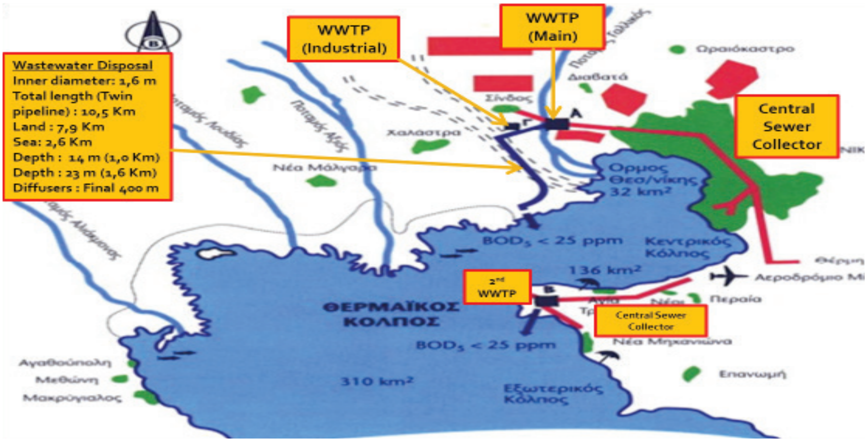


Figure 3-39 Wastewater management in the Thessaloniki area

Figure 3-40 Central sewerage collector of Thessaloniki

The central sewerage collector of Thessaloniki has a length of 16.2 km total (11.8 km in a tunnel), 6.3 km of pipelines, and utilizes 9 pumping stations.

The main WWTP of Thessaloniki was designed for an equivalent population of 1333000 inhabitants, approximately 300,000 m^3/d and is in operation since 1/5/2000. The annual average influent is estimated at 161,175 m^3/d (receiving 715 m^3/d from sewer tanks). The total organic load is approximated to 55,350 kg BOD_5/d (mean annual).

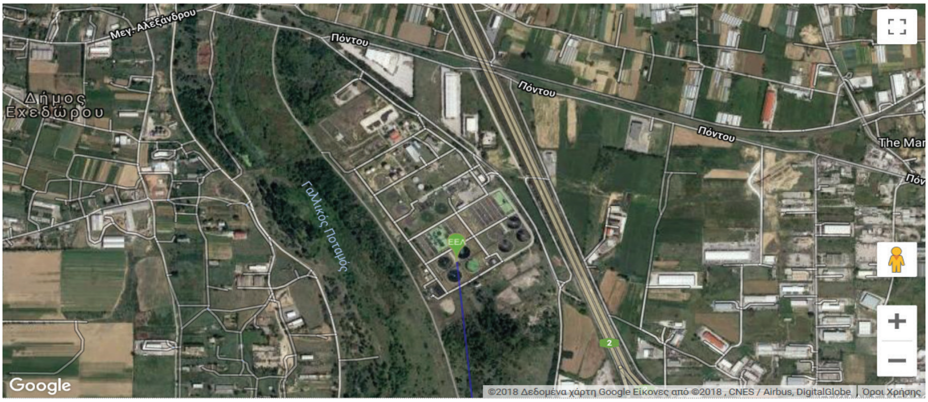


Figure 3-41 Google map of the location of the main WWTP of Thessaloniki

Even though the Gallikos river runs very close to the establishment (Figure 3-41), Thessaloniki's sewage, after secondary treatment, is discharged into the sea through a submarine short outfall, at a safe distance from both rivers, Axios and Gallikos (Figure 3-39). Figure 3-42 shows the entire facility at Sindos, with the sedimentation tanks in front and the aeration tanks for the biological treatment right above, whereas Figure 3-43 shows the fingerprint of the establishment.

Figure 3-42 Aerial photo of Thessaloniki's main WWTP (Sindos)

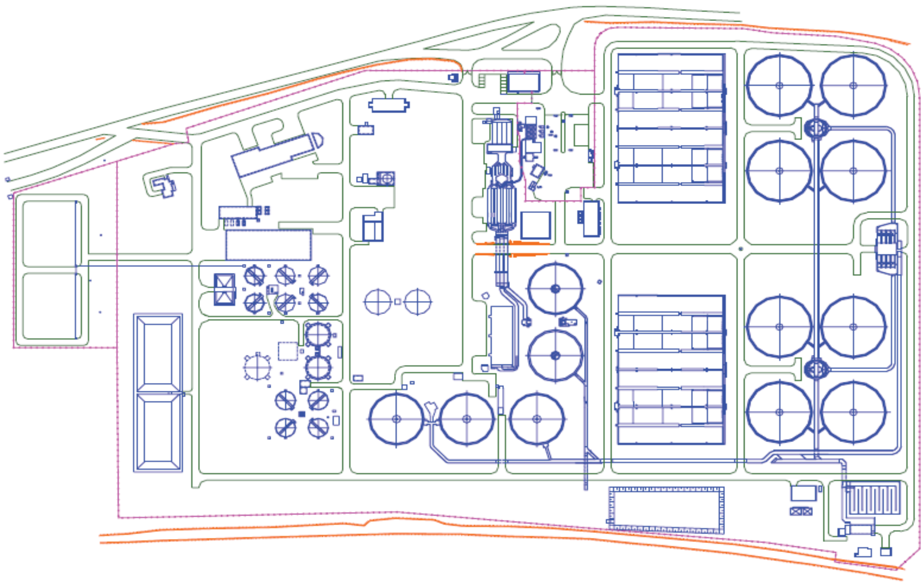


Figure 3-43 Fingerprint of Thessaloniki's main WWTP (Sindos)

The WWTP does not receive industrial wastewater, since there is a separate facility in the area of Sindos. The treatment that is provided to the urban wastewater and its sludge are given in a tabular format (Table 3-14).

Table 3-14 Urban wastewater and sludge treatment, at Thessaloniki's WWTP in Sindos

WASTEWATER TREATMENT	SLUDGE TREATMENT

▪ **Mechanical** or Primary treatment
  ▪ Bars/Screens
  ▪ Grit chambers
  ▪ Primary sedimentation
▪ **Biological** or Secondary treatment
  ▪ Suspended Biomass Treatment (Activated Sludge)
  ▪ Nitrogen (biological) removal
  ▪ Phosphorus (biological) removal
▪ **Disinfection**
▪ **Disposal**
	▪ **Thickening**
	▪ **Stabilization (anaerobic)**
	▪ **Dewatering**
	▪ **Drying**
	▪ **Disposal**

3.7.1 Thessaloniki's wastewater treatment plant

There is a big manhole at the entrance of the WWTP, leading the wastewater into three separate chambers, with three Archimedes screws (lift capacity: 2,3m^3/s each).

Figure 3-44 Archimedes screws at the entrance of the WWTP

The primary or mechanical treatment, which consists of bars, grit chamber, and sedimentation tanks (Figure 3-45), is designed to remove all big size materials, such as trash, tree limbs, leaves, branches, and small size materials such as sand and oil.

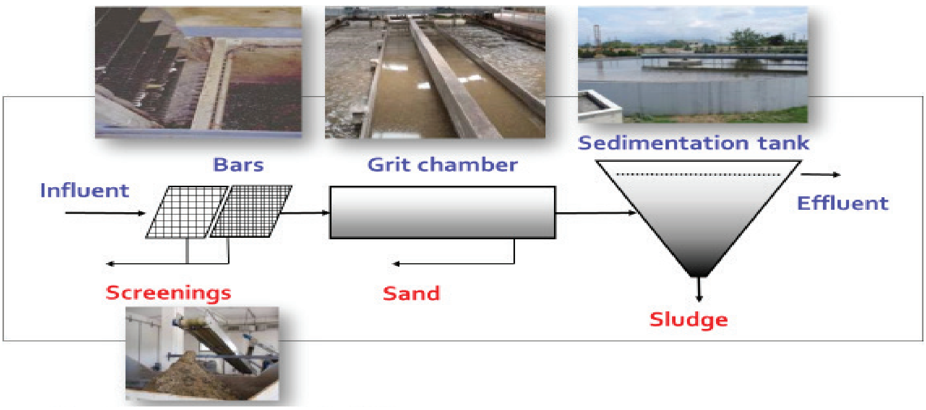


Figure 3-45 Primary or mechanical treatment

Figure 3-46 Bar screens (5 lines) at Thessaloniki's WWTP

The influent passes through bar screens (Figure 3-46) to remove all large objects like cans, rags, sticks, plastic packets, etc. carried in the sewage stream. The bar screens (5 lines) are equipped with grooved mechanical self-cleaning grids (spacing 10mm).

The pretreatment includes a sand or grit channel or chamber (Figure 3-45), where the velocity of the incoming sewage is adjusted to allow the settlement of sand, grit, stones, and broken glass. These particles are removed because they may damage pumps and other equipment. Grit chambers come in three types: horizontal, aerated, and vortex grit chambers. The grit chamber consists of two twin longitudinal, aerated tanks with bubble diffusers. There is a bridge with submersible pumps which are scanning the tank and collect the sand, sending it (after washing) to a drainage system for drying and removal. Floating scrapers collect the fat and grease which floats on the surface.

Figure 3-47 Stormwater tanks in Thessaloniki's WWTP

Since Thessaloniki's sewerage system is combined, the WWTP is equipped with two circular tanks for stormwater (D = 47m and V = 5.000 m^3) each (Figure 3-47). They are operating with rotating sludge scrapers. They have the capacity to store the excess supply (rainfall and stormwater). They can be discharged back to the big manhole at the entrance of the WWTP.

Figure 3-48 Primary sedimentation tanks in Thessaloniki's WWTP

Primary treatment is completed with "primary clarifiers", or "primary sedimentation tanks", or "pre-settling basins" (Figure 3-48). The tanks are used to settle sludge while grease and oil rise to the surface and are skimmed off. Primary settling tanks are usually equipped with mechanically driven scrapers that continually drive the collected sludge towards a hopper in the base of the tank, from where it is pumped to the sludge treatment facility. There are three circular primary sedimentation tanks (D = 47 m and V = 5.000 m^3).

Figure 3-49 Archimedes screw pumps

Following the primary sedimentation, eight Archimedes screw pumps (capacity 1,77 m^3/s each) are used for the interim lift of wastewater and recirculation of the sludge to the bioreactor (Figure 3-49).

Figure 3-50 Thessaloniki's biological treatment

The wastewater is aerated by a diffusion system with underwater rain bubbles (disk type diffusers with graded density), as shown in Figure 3-50. Biological degradation of the organic load and simultaneous nitrification–denitrification is achieved. The first compartment of the tank (anoxic zone) serves as an anaerobic stage for the biological removal of phosphorus. In the anoxic compartments, the desired mixing is achieved by submersible mixers, while the internal recirculation liquid is mixed with submersible pumps wall. There is also the possibility of a future expansion of the bioreactors with two additional tanks.

Figure 3-51 Thessaloniki's WWTP is equipped with 5 aeration units

The air that is conducted to the bioreactors is generated in the compressor building, which houses 5 aeration units (Figure 3-51). Their capacity is 28.500 Nm^3/h each.

Figure 3-52 Final sedimentation tanks at the WWTP of Thessaloniki

The main WWTP of Thessaloniki has eight circular final settling tanks (secondary clarifiers), with a diameter of 54 m (Figure 3-52). They are equipped with diametrical rotating sludge scrapers, which scrape the bottom of the tanks and direct the sludge in the sludge collection chamber, whereas the floating foam is removed from the surface. Each foursome tank is served by a well-sharing effluent flow, from the bioreactors to the sedimentation tank. The recirculation of the sludge is maintained with the aim of electrically adjustable weirs, from the bottom of the tank to the bioreactor.

Figure 3-53 Disinfection of treated wastewater with chlorination

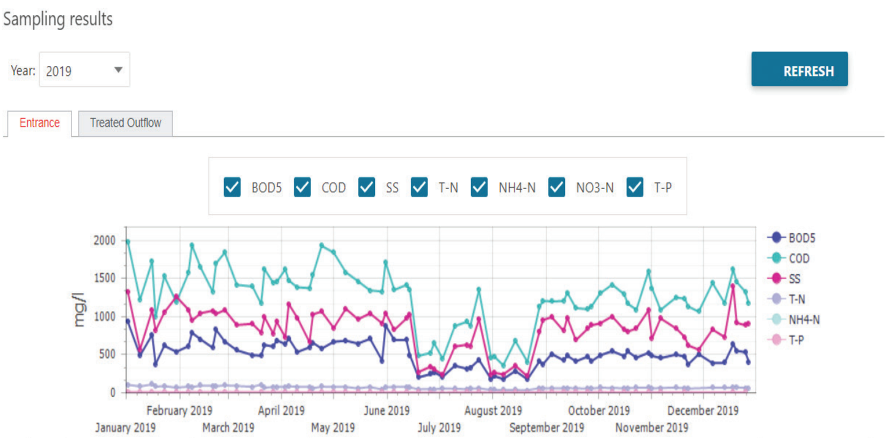
The treated wastewater overflowing the secondary clarifiers is led to the disinfection unit (meander contact tank), as shown in Figure 3-53. Chlorine solution diffusers are used in order to exterminate all the pathogenic microorganisms contained in sewage.

3.7.2 Thessaloniki's WWTP results and efficiency

The quality measurements of the effluents are in compliance with the criteria set by Directive 91/271/EEC and JMD 5673/400/1997 and shown in Table 3-15. Figure 3-54 and Figure 3-55 also demonstrate the graphical results of the most recent measurements at the WWTP inflow and outflow, reported at the site of ypeka.gr, as well as in tabular form. Moreover, Table 3-16, reveals the efficiency of the treatment of wastewater in the WWTP of Thessaloniki, with respect to various parameters.

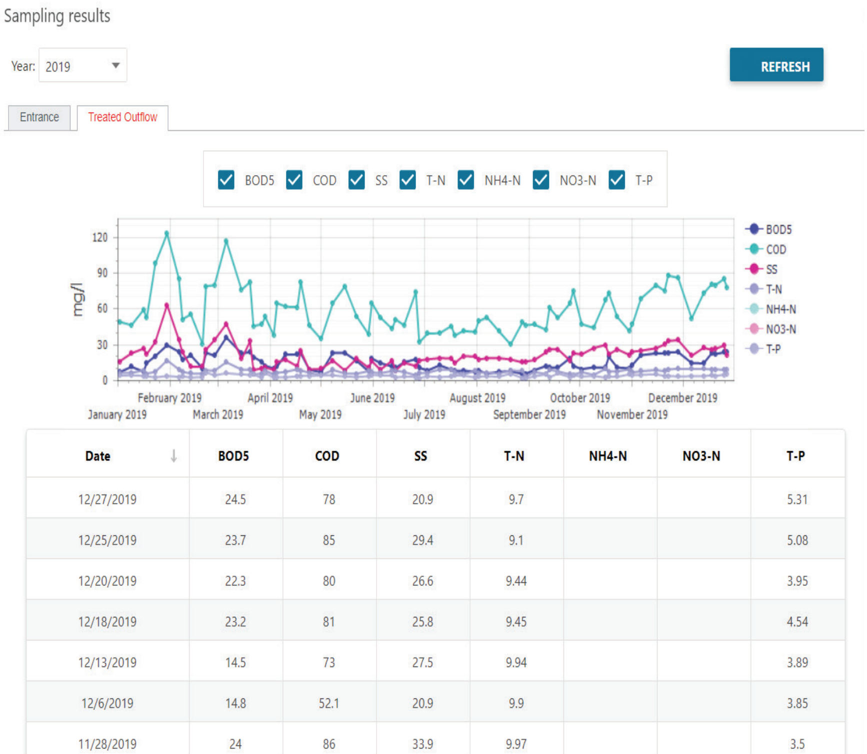
Table 3-15 Quality measurements of effluents

Year	BOD_5	COD	TSS	T-N	T-P
2019	✓	✓	✓	✓	—
2018	✓	✓	✓	✓	—
2017	✓	✓	✓	✓	—
2016	✓	✓	✓	✓	—
2015	✓	✓	✓	✓	—
2014	✓	✓	✓	✓	—
2013	✓	✓	✓	✓	—
2012	✓	✓	✓		—
2011	✓	✓	✓		



Date	BOD5	COD	SS	T-N	NH4-N	T-P
12/27/2019	409	1169	908	65.8		
12/25/2019	533	1327	886	65.4		11.05
12/20/2019	554	1453	920	74.1		
12/18/2019	638	1617	1395	71.1		9.96
12/13/2019	395	1177	734	70.6		
12/6/2019	391	1440	831	70		
11/28/2019	509	1065	568			

Figure 3-54 Sampling results of untreated sewage at the entrance of the WWTP of Sindos (2019)



Date	BOD5	COD	SS	T-N	NH4-N	NO3-N	T-P
12/27/2019	24.5	78	20.9	9.7			5.31
12/25/2019	23.7	85	29.4	9.1			5.08
12/20/2019	22.3	80	26.6	9.44			3.95
12/18/2019	23.2	81	25.8	9.45			4.54
12/13/2019	14.5	73	27.5	9.94			3.89
12/6/2019	14.8	52.1	20.9	9.9			3.85
11/28/2019	24	86	33.9	9.97			3.5

Figure 3-55 Sampling results of treated outflow (2019)

Table 3-16 Reported efficiency of Thessaloniki's WWTP

Parameter	Influent	Effluent	Limits	(%) Efficiency
BOD_5 (mg/L)	657	11,2	**25**	98,3
COD (mg/L)	1849	50,5	**125**	97,3
SS (mg/L)	1015	14,1	**35**	98,6
N_{TOT} (mg/L)	88	6,7	**10**	92,4
P_{TOT} (mg/L)	21	3,8	**10**	82,2
TC (CFU/100mL)	$1,7 \times 10^8$	208	**1000**	99,9
FC (CFU/100mL)	$2,3 \times 10^7$	38	**200**	99,9

Figure 3-56 Treated wastewater disposal to Thermaikos bay, through submarine outfalls

Figure 3-57 Disposal of the effluents from Thessaloniki's WWTP to the sea

A twin pipe is used for the disposal of the effluent. Four pumps (capacity 1,58 m^3/s each) are used to give the necessary potential for the final outlet. The main characteristics of the pipes are given in Table 3-17.

Table 3-17 Effluents disposal

Inner diameter: 1,6 m	Total length (Twin pipeline): 10,5 Km
Inland: 7,9 Km	In the sea: 2,6 Km
Depth: 14 m (1,0 Km)	Depth: 23 m (1,6 Km)
Diffusers: Final 400 m	

3.7.3 Sludge treatment in Thessaloniki's wastewater treatment plant

The following chart shows the consequent steps of sludge treatment at the main WWTP of Thessaloniki.

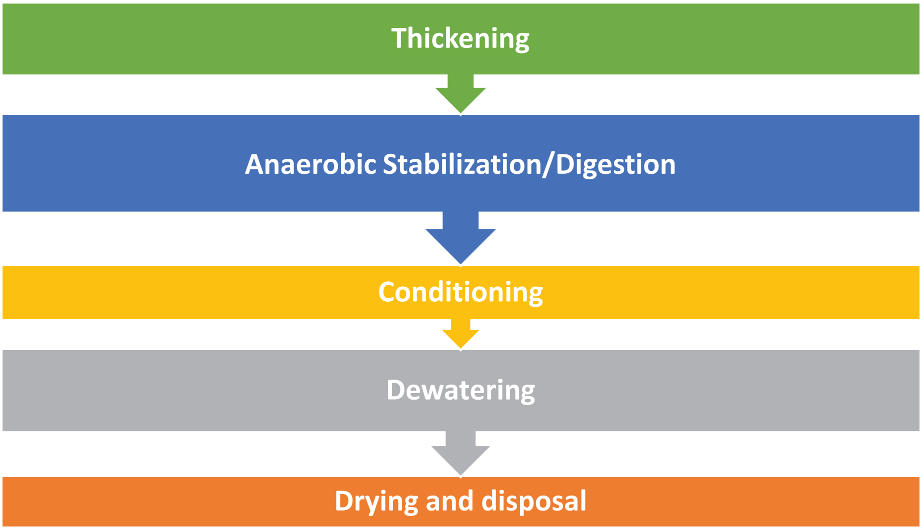


Figure 3-58 Sludge treatment at Thessaloniki's WWTP

- For the **thickening** of the sludge, there are four circular tanks (gravity thickeners) (D = 15,6m and V = 500m³ each). They are equipped with rotating scrapers mixing sludge. Two Mohno pumps (70m³/h each) send the thickened sludge for further treatment (anaerobic digestion).
- By means of anaerobic microorganisms, at 36° C, the sludge is **anaerobically digested**. The biogas produced is used in the installation. There are two large closed cylindrical tanks (V = 7.500m³ each) while there is scope for another. Each tank has its own premix system - preheating of the sludge, while the evolved gas is collected in two cyclical reservoirs (V = 2.000 m³ each), while the excess amount of gas not utilized in the installation goes for controlled burning to a torch. The compressors used for sending the biogas for mixing the sludge in the anaerobic digester and the boilers, which are used to preheat the digester, are located in a separate building.
- **Post-thickening** of the sludge is taking place in six circular gravity tanks (D = 15,6 m and V = 500 m³ each). Then three Mohno pumps (107m³/h each) are sending the sludge to the homogenization tank.
- The sludge is treated **(thickened)** in two closed turnstiles. Their capacity is 108 m3/h. A solution of polyelectrolyte is also used in the process. The thickened sludge is then sent to the homogenization tank. In the homogenization tank, the mixture of primary and secondary sludge is homogenized. The dehydration step (fed by gravity) follows.
- **Dehydration** is conducted by five band filter presses, fed by five Mohno pumps (30 m³/h each). The addition of polyelectrolyte in the blended slurry

gives the final dehydrated product containing up to 23% solids. The final product is treated (and sterilized) with lime.

Finally, there is a drainage network for the leachates (collected by gravity) from the pre-thickening, thickening, post-thickening, and mechanical dehydration, sending them back to the inlet pumping station.

3.7.4 Treated wastewater reuse from Thessaloniki's wastewater treatment plant

Thessaloniki's Water supply and Sewerage Company (E.Y.A.Th.) is operating two pilot programs, in the vicinity of the main WWTP in Sindos. Treated wastewater is mixed with irrigational water, in order to provide water to corn crops (Figure 3-59). Groundwater artificial recharge in the vicinity of Gallikos river, is also performed, through injection wells (Figure 3-60).

a.) b.)

Figure 3-59 a.) Corn irrigation in Sindos b.) A mixture of treated wastewater with irrigational water

Figure 3-60 Groundwater artificial recharge in the vicinity of Gallikos river, Thessaloniki Prefecture

4

Wastewater management of the Dojran/Doirani Lake

4 Wastewater management of the Dojran/Doirani Lake

by Darko Babunski

Wetlands are vulnerable to human and climatic effects (Babunski, 2017). Lake Dojran like all the rest of wetlands is no resistant to human and climatic effects. Drop in the water level, receding the lakeshore, water pollution, reduction in biological diversity, accompanied by destroyed fisheries industry and tourism, are the main issues of the Dojran lake and the surrounding. Being a shared water body of both North Macedonia and Greece, it is just one more confirmation that bilateral cooperation is necessary for improving its condition, hence the environment and life quality.

4.1 Facts and figures

Lake Dojran with its richness of fish fauna is one of the most unique lakes in Southeast Europe. It is a closed hydrological basin with a perimeter of 26.20 km, out of which 14.80 km (56.49%) belong to the North Macedonia side and 11.40 km (43.51%) to the Greek side. The length of the Lake amounts to 8.9 km, and the biggest width is 7.1 km. The average depth is 6.7 meters, while the deepest point is at 10 meters. In the period before the decline of the level, the area of the Lake was 42,5 km^2 (the water level above the sea level of the lake is 148 m), while at present it has reached 32.5 km^2. It is a tectonic lake, a relic of the large ancient lake Paionia, one of the last lakes of the old Aegean group of lakes. Lake Dojran has a unique ecosystem characterized by a specific biocenosis, which makes it a significant natural asset and a valuable resource for communities around the lake. Its water quality is characterized by high alkalinity and elevated carbonate and magnesium hardness. As mentioned, pollution is caused by municipal wastewater, municipal solid wastes, sewage from tourist facilities, and agricultural point source, and non–point source pollution, and its impacts are felt in both countries. Additionally, concentrations of certain toxic substances are near or even beyond toxic levels. In Greece, there are high values of phosphates, low concentrations of heavy metals have been observed in the aquifer.

On the other side, Lake Dojran is one of the priority Key Biodiversity Areas in the Mediterranean biodiversity hotspot (Babunski, 2019). It covers a globally Important

Bird Area[15], Important Plant Area[16], Ramsar site[17] while meeting the criteria for Key Biodiversity Area, and the reason for being protected as Monument of Nature. Since 2011 its management is under the Municipality of Dojran. After discharging the lake in 1988, due to activities in both countries, as well as its quality reduction as a result of municipal wastewater disposal, its flora and fauna are permanently disturbed which also led to mass extinction over 140 of species, according to biologists. Water abstraction has also been a pressure factor for the underlying aquifer, resulting in the decline of groundwater level to 1.5 m below its permitted hydro-biological minimum. Leading to the conclusion that a considerable number of local people will be left with no income in case fisheries collapses completely, going hand in hand with that the deterioration trend in tourism would most than certainly follow any further degradation of Lake Dojran (Anon., 2001).

The situation was aggravated by the low precipitation in the period 1989-1993, and high evaporation rates in the lake basin. Over the last 20 years, the lake's level has also dropped continuously due to increasing Greek abstraction, mainly for irrigation purposes. The most extreme water level and water volume decreased from 262 × 106 in 1988 to 80 × 106 m^3 in 2000. The anthropogenic pressure had not been greatly modified over the last 20 years, but the severely decreased water level and the shortage of self-purification mechanisms resulted in hyper-eutrophication of Lake Dojran, which confirms that only a bilateral approach to the management of the lake will lead to lake remediation.

Figure 4-1 Lake Dojran

15 http://datazone.birdlife.org/home
16 Important Plant Area
17 https://www.global-wetland-outlook.ramsar.org/

During the last 15 to 20 years, the natural aging process in the Lake of Dojran has been accelerated by the activity of the human factor. People with their activities can intensify the natural processes of aging and extinction and shorten the time of the Lake's ecosystem existence. This has exactly happened in the case of Dojran lake. Such process was exceptionally present in 1988-1989, when peopled used the Lake's water in an uncontrolled manner and allowed the loss of huge quantities of water from the Lake, further burdened by a long dry period. With the rapid loss of part of its surface area and enormous reduction of its water volume, the lake suffered from the disturbed ecological balance which was a stress for the living world in the Lake. Based on the completed sanitary and hygiene tests, the water in the Lake of Dojran, at all measuring points, considering its bacteriological safety, belonged to II and I class of surface water in accordance with the decree on waters classification. With regard to tested physical and chemical parameters (turbidity and saturation), the water in the Lake of Dojran is classified in IV - V classes of surface waters, while in relation to the presence of organic matters, pH value, iron, BOD_5 in III class. With reference to other parameters, the water in the Lake of Dojran belongs to II and I class of surface waters.

The lake from North Macedonia, is being recharged by water coming from the Gjavato wells through a pumping and transfer system that has a capacity of 1 m^3/s, as projected in the "Feasibility study on Dojran lake salvation" which has been financed by the Ministry of Environment and Physical Planning and the Ministry of Agriculture, Forestry and Water Economy in 2001. As it is well known, the last two-three years have been much more favourable in hydrological terms, compared to the 20-25 preceding years, which has stopped the process of water-level decline. The newly constructed hydro-system for water replenishment to the Dojran Lake (2002), operational until now, has contributed to this improvement. At the moment, the system operates with a reduced capacity of around 400-600 liters per second (it has been designed for 1000 l/s), its contribution to the status promotion is obvious.

Fortunately, in the last few years, rich rainfalls and floods have helped in increasing the lake volume, almost near to a close level to that before the violent catastrophe. According to the estimates, the former reached absolute minimum (3.88 meters below the zero point) has increased by around 1.8 m, which means that there is still a lack of 2.08 meters in water pillar in order to achieve the zero point at the water measuring strip and then to initiate the process of water pillar filling of 2.40 m which is above the zero point, but currently lacks. The water pillar could be regarded revived even in such case, and that is the height of 147.34 meters above the sea level, which would mean that the Lake has regained its original 262 million m^3 of water, and thus the process of its revitalization, at least in relation to the total water volume, would be completed.

A project activity (Regional Centar for Envrionment, 2015) for improving the ecological conditions has conducted analyses which led to the conclusions:

The basic physio-chemical parameters measured during the conducted three scientific-educational camps during the spring-summer-autumn 2015 seasons on Lake Dojran and Nikolichka River, indicate that the lake has extremely high values of the main waste/nutrients, phosphorus, and nitrogen. compounds, which are within the limits of V category according to the domestic legislation for water classification; The measured values far exceed the concentrations of these substances recorded so far in any aquatic ecosystem in the country. This condition directly affects the high conductivity of water (an indirect measure of the presence of ions), the amount of dissolved oxygen which varies greatly, and the concentration of chlorophyll as a measure of the presence of phytoplankton in the lake. All measured parameters have a clear trend of deterioration from spring to autumn. Indications have also been identified that the Nikolichka River contributes to the total load on the lake ecosystem. According to these parameters, the lake is in poor ecological condition.

The algal flora has also been analysed and the findings are that the high concentration of nutrients leads to the mass development of cyanobacteria (blue-green algae) in plankton that form a “water flower” and colour the water mostly green. This makes the lake water polluted and full of toxins, which indicated that the Dojran Lake is in a very bad ecological condition.

Two dominant species, the ostrich and the line, and on subdominant the Moor (Pachychilon macedonicum) are inhabiting the lake. These results differ from data in 2009 when 46% dominance was form carp followed by redfin with 22%, the scarecrow (belvica) with 12%, and the cost with 5.5%.

All in all, there is insufficient scientific baseline data for the condition of Lake Dojran and the clear linkages between the contribution of human and natural factors on the current state of the lake. All the necessary measures must be taken to ensure compatible data of comparable quality and quantity in both countries. One way to achieve this would be through joint research projects which would address the appropriate financial resources and would utilize existing institutes and suitable experts. At the same time, immediate rescue measures should be identified and be put forward in parallel with medium and long-term measures. The measures should be in the area of water management, environmentally-friendly agriculture, wetland conservation, recreation facilities, ecotourism development, and the development of infrastructure, including treatment plants for the domestic effluents of local settlements. The objective is the establishment of a management system for the area. Lake Dojran is included in a Specially Protected Area according to the Directive 79/409/EC (Conservation of wild birds). Both North Macedonia and Greece have obligations with regard to water management, arising from the adopted Water Framework EC Directive and the national legislations, defining the relevant water basin district by both countries. All international conventions formerly signed are still in force, but according to the bilateral agreement on transboundary water issues, dated back to 1960, which foresaw a joint committee that was never formed. The establishment of that committee, which could propose friendly arrangements with regard to problems associated with Lake Dojran, should be a high priority.

An Assessment of the State of the Environment in the Municipality of Dojran has been carried out by application of the DPSIR methodology. The Ministry of Environment and Physical Planning of North Macedonia used this methodology while preparing the Second National Environmental Action Plan under the Project "Technical Assistance for the Development of the NEAP II" financially supported by the EU. The Driving Force - Pressure - State - Impact - Response enables to define driving forces that make impacts on the environment, determination of the state, the pressure, the impacts on the environment, as well as to identify the appropriate response in line with the linkages and relations presented on the scheme below.

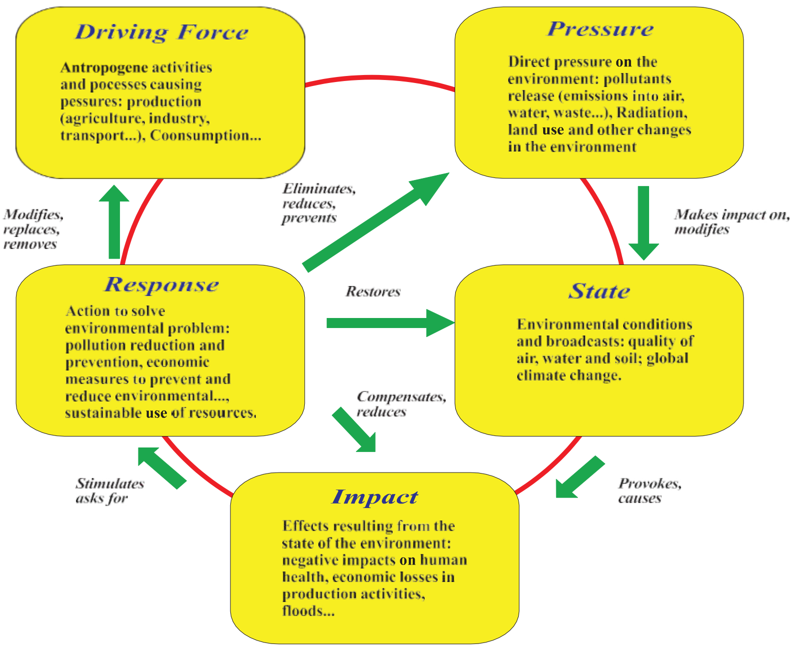


Figure 4-2 DPSIR methodology for the impact on the environment

4.2 History

In the past, a Bilateral Agreement was concluded between the Government of the Federative Peoples Republic of Yugoslavia and the Government of the Kingdom of Greece on 9 June 1956 for the undertaking of measures in relation to the high-water level. The Yugoslav side was the only one showing interest in the issue of the high-water level of the Lake, in order to avoid problems in the context of the specific manner of fishing and flooding of the agricultural land limited at that period. On the other side, Greece, had a clear position: to irrigate as much as possible land areas outside the watershed area, i.e. the fields in Dojrani - Kristonija, water supply in vegetation period, as well as for electricity production in the winter period, under conditions of a high-water level of the Lake. For irrigation and other uses, the Greek side agreed to the maximum water utilization up to the water pillar height of 1.2 m (from the highest point in the Lake at 146 meters above the sea level, and the lowest at 144.80). By 1975, the water level was maintained mostly in compliance with the Agreement, i.e. 4 cm from the minimum level. From 1976 to 1987, the water level in the Lake was below the minimum agreed level almost every year, although the average precipitation amounted to 648 mm, while precipitation in vegetation period was 278 mm; however, water evaporation from the Lake was high (above 800 mm). Thus, the cause was not the dry period, but the excessive and irresponsible water usage by Greece, in breach of the 1956 Agreement. In the period from 1988 to 2000, the water level in the Lake noted permanent decline, reaching a lower absolute minimum almost every year. As a result, from water loss, the Lake reached the lowest point (3.88 meters below the zero point). This, in combination with the previously lost water pillar above the zero point (2.40 m) means an actual reduction of the water pillar of the Lake by a total of 6.28 meters. Such water loss, in a lake with a maximum water depth of around 10.0 meters, is drastic and equal to disaster. This low water level has led to rapid and undesired changes in the lake's aquatic ecosystem, i.e. its flora and fauna. The reduced water volume caused a rise in the water temperature, including the one in the lower layers of the water pillar, which has further intensified the processes of eutrophication and trends towards the death of the Lake as a specific ecosystem. In fact, having reached the lowest point (3.88 meters below the zero point), the total water volume of around 262,0 million m^3 as an agreed maximum declined at only around 60-70 million m^3, reflecting a loss of around 200 million m^3 of water.

4.3 Water protection

It is necessary to establish a monitoring system and permanent observation of certain parameters, including the measurement of pesticides and heavy metals, in order to have constant in-sight in the status of the lake's system and undertake preventive measures. Dojran Lake protection and supply of water in order to return the original water regime should be one of the priority projects, including full operation of the system for additional water quantities delivery to the Lake from the springs located in the fields of Gjavato.

For the purpose of Dojran Lake protection against wastewater, a system for Dojran lake protection has been developed alongside the shoreline (wastewater collection system and treatment plant), put into operation in 1988. The wastewater treatment plant "Toplec" was built in 1988, as the final point of the eastern and western collection branches. The pressure pipeline of a ø 350 mm, has a maximum capacity of 160 l/s and a length of 2.250 meters to the outlet at the height of 211.80 transports the treated water from "Toplec" to the discharge point at the river of Luda Mara, a tributary of Anska River. As a result, from the Lake's water level decline, the number of tourists during tourist season declined, too. This issue, together with the negative birth rate and migrations from the area, contributed to the fact that the existing wastewater treatment plant became too large and extremely inefficient in terms of cost-efficiency of operations. For this reason, in 2001, the reconstruction of the plant introduced new mechanical and biological treatment technology, with significantly lower electricity consumption and capacity able to respond to the demand during and outside tourist seasons. The newly reconstructed plant has a maximum designed capacity for 1800 equivalent inhabitants and consists of two Bioblocks. The Bioblock 1 has a capacity of 600 equivalent inhabitants and is under regular operation. Bioblock 2 has a maximum capacity of 1200 equivalent inhabitants, but it also contains equipment for a capacity of 600 and 900 equivalent inhabitants and it is put into operation during the summer season. The technology used for the wastewater treatment provides for full wastewater treatment. The treated water is then disinfected and with the remaining pollution level amounting to a maximum of 20 min BOD_5/l it is pumped to the basin of the river of Luda Mara where it has satisfactory water quality that can be used for irrigation of the crops grown in this area. The utilization rate of the wastewater treatment plant capacity is 23%, because the number of households connected to it is 397, while the rest of the population of the Municipality of Dojran uses septic tanks. This situation could result in groundwaters contamination and consequently in reduced drinking water quality used by inhabitants in the villages.

Lake Dojran has long been characterized as a eutrophic natural lake. However, recent events, particularly the decline in water level due to anthropogenic impacts and a prolonged dry period, have begun to accelerate the lake toward a higher eutrophic state. Taking into account the need for achieving a good chemical and biological status in the Lake's waters, the establishment of sewage networks and construction of wastewater treatment facilities should proceed.

As far as the current situation concerns, regarding wastewater treatment facilities in the Dojran catchment, the situation is as follows: On the Greek side (villages of Akrita, Amaranta, Agia Paraskevi, Mouries, Myriophyto, and Mouries RS), septic tanks are used for the collection and treatment of wastewaters at the household level. Only in the village of Drosato (1,392 inhabitants in the year 2001 approximately 33 % of the total population in the catchment), a wastewater sewage collecting system and a constructed wetland have been established for that purpose, which is operating from winter 2005. It is noteworthy that both sides may examine the use of constructed wetlands, since (for various reasons) these systems are ideal for small municipalities, have low maintenance cost and high treatment potential. Additionally, the potential of establishing plants for the treatment of industrial wastewaters in North Macedonia should be investigated for those industries affecting Lake Dojran and lacking such facilities.

Any restoration measure dooms to fail, in the absence of a monitoring system. A well designed and well-functioning monitoring system may act as the basis for the judgment of the success/failure or the need for alteration of a restoration measure. Furthermore, lake Dojran's drop in water level significantly affects its physicochemical, and biological quality elements. The establishment of a monitoring system, that will provide continuous data to both countries, is thus considered necessary. Monitoring will be carried for parameters indicative of the biological, hydro morphological, and general physicochemical quality elements, most sensitive to pressures to which lake Dojran is subject. Taking into account the requirements of the European Water Framework Directive (60/2000/EC), the monitoring program shall include at the minimum, the following parameters:

- Surface waters
- Lake's Dojran water level.
- Discharge (for the streams inflowing lake Dojran on a regular basis).
- Physicochemical water quality data (NH4-N, NOT-N, NO3-N, PO4-P, Dissolved oxygen, Biochemical Oxygen Demand, pH, Electrical conductivity, Turbidity, and Visibility-Secchi disk)
- Biological quality elements
- Groundwaters
- Fluctuation of the groundwater table

The monitoring system also includes measurement of meteorological parameters in the watershed (i.e. air temperature, precipitation, relative humidity, solar radiation, wind velocity — direction, barometric pressure, and evaporation).

Furthermore, and given that the area of Lake Dojran has been designated as a Special Protected Area, the monitoring system includes monitoring of birds' dependent on water.

Figure 4-3 Measurement points Д1, Д2 and Д3 and control points by the input of two streams P1 and P2, for the measurements in 2015

The water quality has been tested through measurements of the basic physico-chemical properties of the water of Lake Dojran.

Table 4-1 Measurements of the basic physicochemical properties of the water of Lake Dojran

	I CAMP				II CAMP				III CAMP		
Parameters	T1	T2	T3	R1	T1	T2	T3	R1	T1	T2	T3
Max. depth (m)	4	5,5	8	/	5	4,8	8	/	5	4	8
Temperature (°C)	22,6	24,7	22,9	26	24	25	24	29	23,4	25,6	23,5
Dissolved oxygen (mg/L)	9,4	9,2	9,2	7,9	4,5	2,5	5.7	7,9	10,7	6,1	8,1
pH	7,64	7,88	8,04	7,8	8,23	8,60	9,27	8,53	9,39	8,78	8,86
Conductivity (µS)	582	646	638	140	750	722	686	193	705	725	735
Secchi depth (m)	4	4	4	/	3	2,2	2,7	/	1,2	0,9	1,2
Total Phosphorus (µg/L)	90	150	170	150	120	210	200	110	280	380	150
Total Nitrogen (µg/L)	600	1900	800	1200	600	6 400	1 100	410	980	730	1320
Chlorophyll a (µg/L)	2	0,9	0,332	/	11,88	3,88	4,26	/	13	22	17
Pottasium (mg/L)	7,5	9,5	8,8	1,8	9,5	7,0	7,2	1,6	11	8,9	6
Ammonia (µg/L)	50	20	20	< 10	60	< 20	< 20	80	140	180	50
Nitrates (µg/L)	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	2500	1500	<1000
Nitrites (µg/L)	< 10	12	< 10	< 10	< 10	< 10	< 10	< 10	19	36	<10

According to the table, measured values of basic parameters (total phosphorus and nitrogen) during spring, summer, and autumn, are very high, which leads to continual pressure of the lake ecosystem with organic waste (probably from uncontrolled communal wastewater). Values of the Nitrates, Nitrites, and Ammonia are basically beyond the maximum level because they are nutrients to the algae. During spring and autumn, the quality of water decreases, which is clearly shown thru the measurement results (secci – transparency, chlorophyll, conductivity), and there is a rapid development of algae blossoms (mainly from blue-green algae: Cyanophyta, Cyanobacteria), and the value of Dissolved Oxygen in the water is very high because of photosynthesis. Campaign measurements are not enough for serious analysis of the water pollution, for which continual monitoring of the basic parameters is needed, but even with these measurements can be concluded that the current situation with water quality in the Lake Dojran is bad, with continual pressure from waste nutrients to the lake ecosystem, which leads to the categorization of the water body into the fifth and worst category.

5

Wastewater management of the Prespa Lake

5 Wastewater management of the Prespa Lake

by Zoran Markov

5.1 Facts and figures

Prespa Lake (UNDP Macedonia, 2009) is located at an altitude of 850m consists of two interconnected lakes: Micro Prespa (47.4 km^2) and Macro Prespa Lake (259.4 km^2). The watershed is divided between North Macedonia, Greece, and Albania. The area of the lakes, together with the slopes of Pelister, Galicica, Mali i Thate, Varnountas, and Triklario is 1386 km^2.

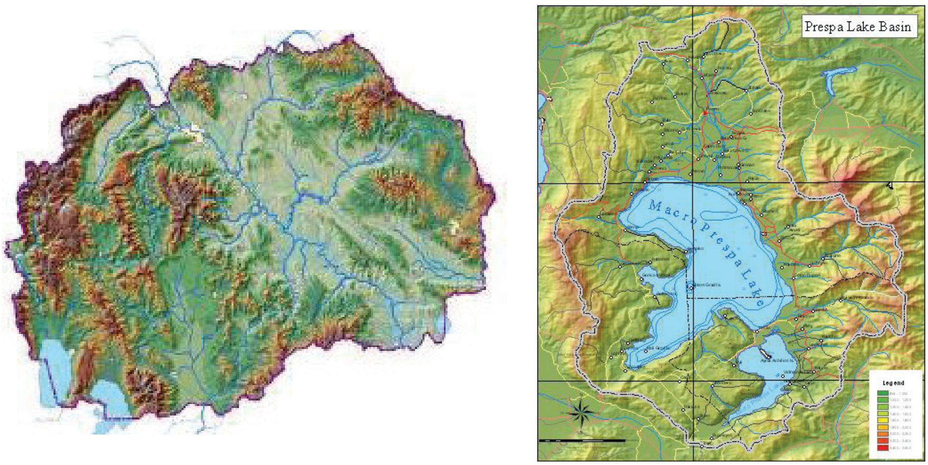


Figure 51 Location of the Prespa lake

Most of the region (part of the watershed that lies in North Macedonia) is classified as a hilly and hilly-mountainous region. The surface of the watershed is divided between the Prespa valley and the mountains in the surroundings: Baba, Ilinska, and Galicica. The surface in the hilly-mountainous part of the watershed is classified as rather steep (the average slope is greater than 32%).

The Prespa region is characterized by a very complex geological-tectonic structure with rocks from the oldest Paleozoic formations to the youngest Neogene and Quaternary sedimentary rocks. The mountains and the valley are mainly composed of rocks that differ in age and composition.

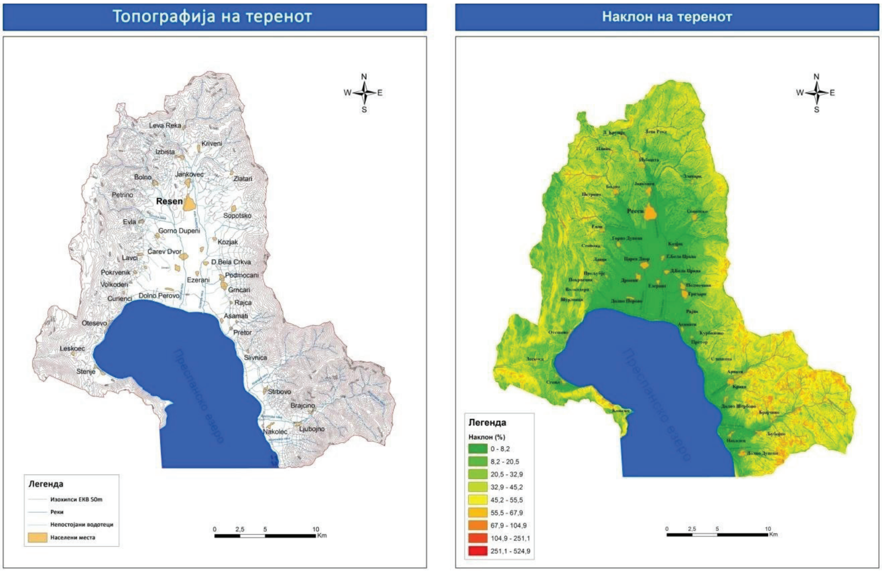


Figure 5-2 Topography and inclination of the Prespa Lake

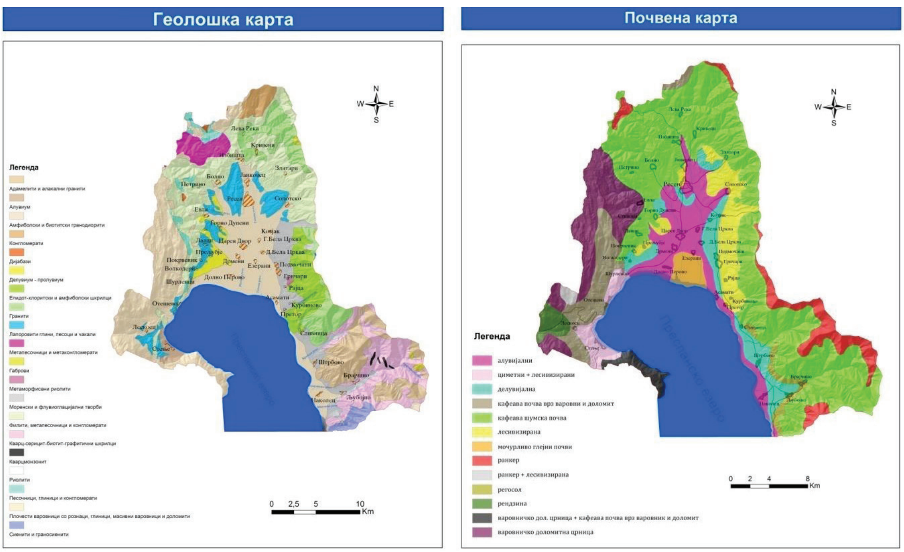


Figure 5-3 Geologic and soil map

The specific orographic conditions that influence the dynamic factors of the climate, together with the influence of the geographical and local factors, created conditions for three different types of climate throughout the basin: hot and cold sub-

Mediterranean climate area, sub-mountain and mountain continental area, as well as subalpine and alpine climatic zone. The average annual temperature is relatively low, but still very suitable for orchards, especially apple trees. The specific local warm-continental climate is created under the influence of relief, altitude, fluctuation of the water of Lake Prespa, and the mild influence of the Mediterranean climate.

The Prespa Valley is surrounded by mountains: Petrinska Planina, Galicica, Suva Planina, Ivan Planina, and Suva Gora. Both the mountains and the valley are mainly composed of rocks that differ in their age, mineralogical composition and origin. Limestone rocks are dominant, and to a lesser extent distributed among Grand Roritic igneous rocks. Sienites are present in areas at higher altitudes, but Triassic carbonate rock masses are also present in many areas. Different types of Quaternary sediments such as alluvial, fluvioglacial, proluvial, organogenic-swampy, and diluvial sediments are dominant in the valley, especially in the riverbeds.

The Prespa valley, as part of the Western part of North Macedonia's hydrogeological region, is characterized by the presence of rocks with different hydrogeological characteristics and type of porosity (fractured/broken, closed, karst and karst-fracture type of aquifer), as well as the appearance of mineral and thermo-mineral groundwater.

Dominant soils in the Prespa Valley are alluvial soils located in the lowest part of the region. A significant part of the valley area and the hills on the west side are used mainly for agriculture. Cambisols are dominant in the mountainous region and are covered with forest vegetation. There is only grass vegetation on the subalpine and alpine terrains. In the part of the basin that lies in North Macedonia there are small deposits of marble, dolomite, limestone, and peat. The main mineral raw materials are limestone and dolomite in the western part. Sand and gravel are exploited around the delta of Golema River in Lake Prespa.

Vegetation varies from submerged aquatic formations and reedbeds, shrub, spruce, oak and beech forests, mixed foliage, to alpine vegetation. There are a total of 1,326 plant species in Prespa, 23 freshwater fish species, 11 amphibians, 21 reptile species, more than 42 mammal species, including the brown bear, wolf, otter, and chamois, and more than 260 bird species. As a refuge for more than 90 species of migratory birds, Lake Prespa is also home to dozens of species officially registered as critically endangered or vulnerable. Among them is the Dalmatian Pelican, one of the largest flying birds in the world, which seeks sheltered swamps to nest and breed. Worldwide, the largest breeding colony of this species is found on Lake Prespa. From a phytocoenological point of view, the presence of the endemic plant community Lemneto-Spirodeletum polyrrhize aldrovandetosum is most important. Regarding the fauna, the most important is the fish fauna which is composed of 80% endemic species.

The population of the part of the watershed in North Macedonia includes one municipality (Resen) and consists of a total of 739 km^2 of which 177 km^2 is a lake area. There are 44 settlements, 43 rural and 1 urban (Resen city). Only 39 of them are active. The total population is 16,825 inhabitants in 4,848 households. During the last 15 years, there has been a decline in demographics, which is mostly due to local migration in this area. More than 5 percent of the total population of the Municipality of Resen is illiterate, while this figure for the city of Resen is 3.9 percent. Regarding the land use, about 32% of the part of the watershed in North Macedonia is covered by forest. The agricultural area covers 27% of which 16% is cultivated. The remaining 41% consists of settlements, roads, and unproductive land (including the lake area). Agriculture plays a significant role in terms of employment and economic sustainability. Currently, over 60% of the total population of the Municipality of Resen depends on agriculture, mainly on apple production. Industrial facilities: food, textile, metal, chemical, and construction, are mostly medium-sized enterprises and are the largest contributor to local GDP. There is a tourist activity that is not very significant at the moment.

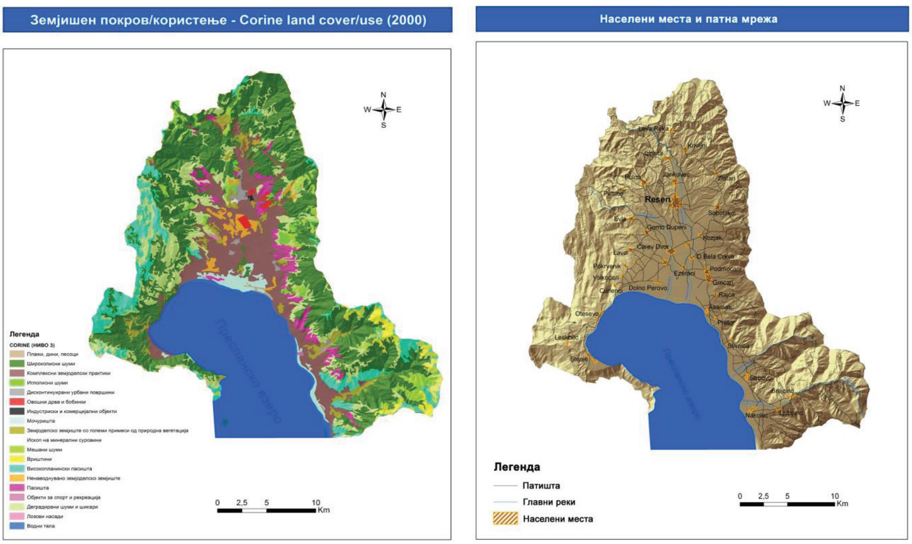


Figure 5-4 Socio-economic maps of Prespa: Populated places and transport network: Land use

5.2 Water-related issues

The connection of households to the water supply and wastewater collection systems is mainly the responsibility of the Public Utility Company "Proleter" (Anon., n.d.). All houses are equipped with water meters, but for the most part, the measurement is common. The measurement and collection of bills is done monthly. Almost all settlements (10 out of 13) within the Golema River watershed are part of the regional water supply system: Krusje - Resen - Sirhan. Only Leva River, Podmocani, and Grnchari are not connected to the central system but are also managed by PCE "Proleter". The system is quite outdated but still provides safe drinking water to users. During the summer, due to the reduced capacity of the wells, in some higher zones, the system lacks a regular water supply.

5.3 Water bodies - location, typology, and delineation

Surface waters

The Prespa Basin consists of two interconnected lakes, the Small and the Large Prespa Lake, which form an inland-mountain basin that has no natural surface outflow. The outflow occurs only through underground connections through which the water of the Great Prespa Lake flows west to Lake Ohrid. The Prespa Lake is at an altitude of 845m above sea level, while Lake Ohrid is 150m lower. On the northern shore of Lake Ohrid, in the city of Struga, there is a natural outflow into the Black Drim. The Micro Prespa Lake is divided between Greece and Albania, while the Macro Prespa Lake is divided between Albania, North Macedonia, and Greece. The Micro and Macro Prespa Lakes are connected by a small natural canal called the Isthmus of Koula. The largest watercourses of the region in the part of North Macedonia are Istocka River, Golema River, Brajcinska River, Kranska River, and Kurbinska River.

The division of the discharged water bodies is made following the rules of the WFD. A total of 16 surface water bodies have been identified, of which: 13 water bodies - rivers, 1 strongly modified water body, and 2 artificial water bodies. The large number of water bodies in a relatively small catchment area is due to the need for accurate assessment of their ecological condition and formulation of specific possible activities to improve the conditions, as well as due to highly variable conditions and conditions along their course (tributaries, condition, status on a natural course or protected area, etc.).

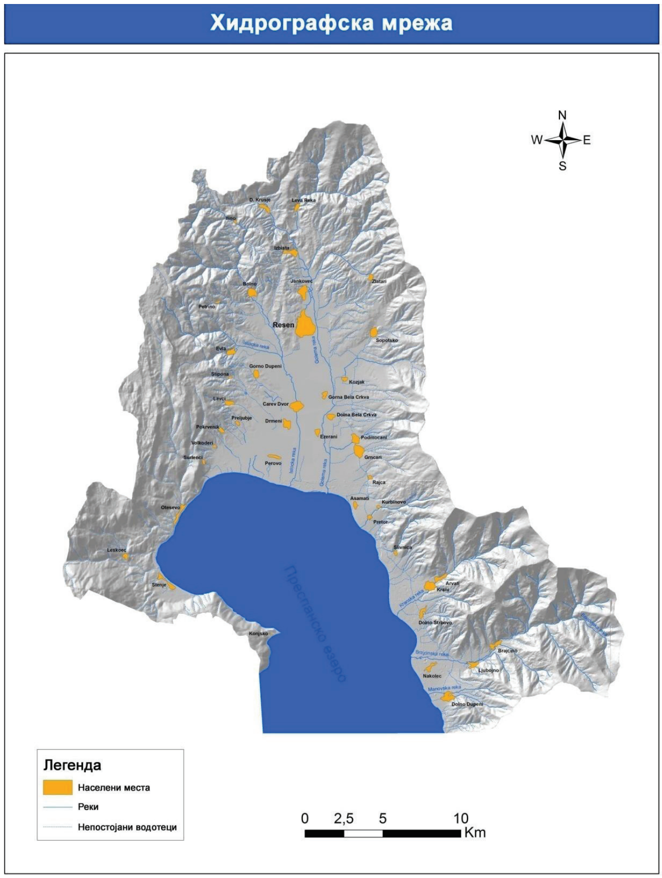


Figure 5-5 Hydrographic network of the lake mouth

The discrepancy thus created between the assessment of the ecological quality of each water body and the difficulties in reporting a large number of water bodies in the later stages of implementation can be revised in the following management plans for this catchment area.

Istocka river (East River) is divided into 3 water bodies:

» Istocka river 1 - part of the river that covers the part of the village. Carev Dvor upstream to the source;
» Istocka river 2 - part of the village. Carev Dvor, downstream to the border of ZP "Ezerani" and
» Istocka river 3 - part of the relay which is within the ZP "Ezerani"

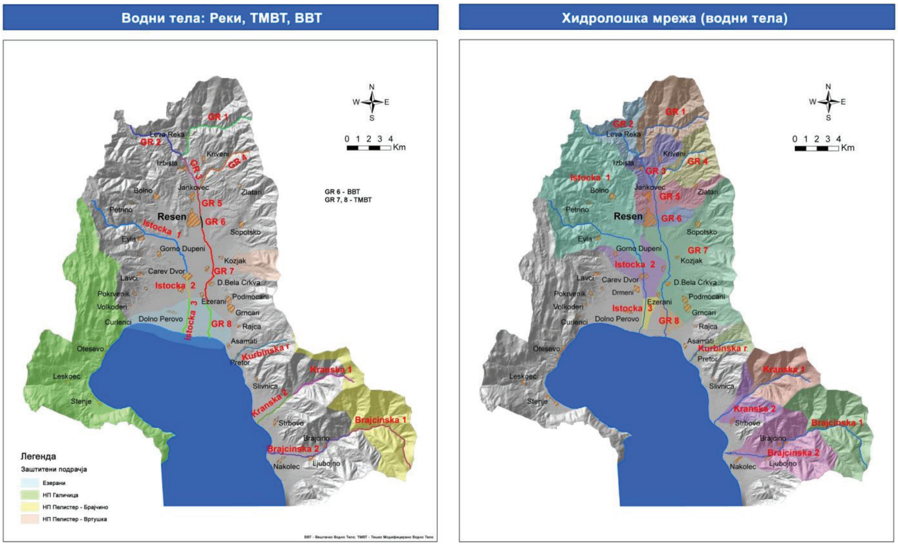


Figure 5-6 Surface water around the lake

Golema River (Big river in translation) is divided into eight water bodies. Five of them belong to water bodies - rivers (Golema River 1 to Golema River 5), one is a strongly modified water body (Golema River 6) and two are artificial water bodies (Golema River 7 and Golema River 8)

- Golema River - section of Leva River (left spring tributary),
- Golema River 2 is the right spring towards the village Krusje;
- Golema River 3 - from the junction of the two spring tributaries to the inflow of Cheshinska River;
- Golema River 4 is Cheshinska River;
- Golema River 5 is the section from the inflow of Cheshinska River to the beginning of the regulation site;
- Golema River 6 is the section in the city where the riverbed is regulated by a concrete canal;
- Golema River 7 flows downstream from the regulation site to the entrance to ZP "Ezerani";
- Golema River -8 is the section within the ZP "Ezerani"

Kurbinska River is a whole water body.

Kranska River is divided into 2 water bodies:

- Kranska River 1 flows upstream to the village Arvati,
- Kranska River 2 flows downstream of this village.

Brajcinska River is also divided into 2 water bodies:

» Brajcinska River 1 belongs to NP Pelister,
» Brajcinska River 2 flows downstream from the village Brajcino to the entrance of the lake.

The whole Lake Prespa is considered as one water body. In the case of complete delineation, then it is proposed that Micro Lake be a separate water body.

The following parameters are used for the typology of water bodies:

» Ecoregion – it belongs to Ecoregion 6;
» Altitude – mountain = H>800m;
» Basin size: Two medium, the rest are small;
» Geological substrate: Two with the presence of carbonate in predominantly silicate substrate, the majority are with silicate substrate.

Consequently, all rivers belong to the same type.

5.4 Water quality

According to the National Law on Waters from 2008 (Official Gazette of the Republic of North Macedonia, No. 87/08) as well as the Water Framework Directive, a requirement for all surface water bodies for classification according to their ecological status, must be met. Groundwater bodies should be classified using two-state classes:

» quantitative and
» chemical state

The main goal is that all water bodies have to achieve "good environmental status". And the state classes are formed based on reference bodies for waterbodies defined as "insignificant or only very small, anthropogenic changes" compared to "reference conditions".

In addition, all further deterioration of the existing state of surface and groundwater should be prevented.

There is an existing Transboundary Diagnostic Analysis (TDA, 2010) (UNDP, GEF, n.d.) conducted for the Prespa Lake, which aims to establish facts to determine the significance of the sources, causes, and effects of pressures in the watershed. The TDA presents the facts related to the problems that exist in the basin and the pressures and stresses of the ecosystem.

Considering the cross-border nature and the consensus reached, the environmental objectives identified by the TDA are taken into account to elaborate the Prespa Lake Basin Management Plan. In this way, the side in the part of North Macedonia has taken a very important first step in accordance with the mutually agreed cross-border priorities.

The TDA identifies five priority issues in a cross-border context: poor water quality (nutrients, organic and hazardous substances, pollution); inadequate land management; unsustainable fishing management; the decrease of the lake level, and the large transport of sediments.

The TDA report has identified several environmental goals, divided into long-term (10 years), medium-term (5-10 years), and short-term (1-5 years).

Ecosystem status and treats (Ivanovski, 2009)

The local economy which is based on agriculture, tourism, and fishing initiates a serious decline of the water level of the Prespa Lake, which results in eutrophication and loss of littoral habitats. The main issues leading to that are ineffective land-use and water use planning, insufficient wastewater management, lack of implementation of environmental and water law. Additionally, there is no controlled use of pesticides, fertilizers, and other hazardous and dangerous substances used in agriculture, which influences the decline of the water quality. Also, the waste management practices are not appropriate for maintaining a clean and safe waterbody.

5.5 Trilateral Cooperation

Being a shared waterbody between three countries, North Macedonia, Greece, and Albania, mutual cooperation and responsibilities are necessary for the water body and the environment protection. Therefore, there is a signed Agreement on the Protection and Sustainable Development of the Prespa Park Area (Anon., 2012), as a consequence of the Trilateral Declaration– signed 02 February 2000. With the support of UNDP/GEF, Integrated Ecosystem management in Prespa Lakes Basin in Albania, North Macedonia and Greece have been conducted. With this plan, the following objectives and goals have been achieved:

- » Catalyzing the adoption and implementation of ecosystem management interventions that integrate ecological, economic, and social goals whilst conserving globally significant biodiversity and reducing pollution of the trans-boundary lakes;
- » Mainstream ecosystem management objectives and priorities into productive sector practices and policies;

- Strengthened capacities for restoring ecosystem health and conserving biodiversity by ecosystem-oriented approaches to spatial planning, water use management, agriculture, forest and fishery management, and conservation and protected area management;
- Strengthened ongoing trans-boundary cooperation by empowering the existing trans-boundary institution and implementing trans-boundary management and conservation activities.

For efficient outcomes, the activities have been split nationally and transboundary, whereas the national tasks have been:

- to develop a watershed management plan for the part of the Prespa Lake that lies in North Macedonia;
- to mainstream ecosystem management priorities into sectoral legal & regulatory; instruments, policies, and plans;
- Establish integrated pollution prevention and control system at a local level;
- Introduce Good Agricultural Practices (GAP) and agricultural waste management system;
- Support development of ecosystem-oriented forest management plans;
- Demonstrate decentralized wastewater treatment for small communities;
- Strengthen the national protected areas system;
- Support the transboundary component;

On the other side, transboundary activities consider creating support for the maturation of the Prespa Park Coordination Committee (PPCC) and Conservation Action Planning for Priority Transboundary in order to protect and maintain the habitats and species in Prespa Lakes basin through:

- Identification of transboundary conservation landscape, development, and implementation of priority habitats and species conservation action plans;
- Development of trans-boundary monitoring system;
- Establishment of trans-boundary monitoring of ecosystem health parameters to strengthen information baseline for adaptive management in all littoral states;
- Highly participatory process overseen by the MCWG (representatives from Ministries, scientific/research institutions, NGOs...);
- Enhancement of the transboundary cooperation in fisheries management and promotion of ecosystem-oriented fisheries management;
- Agreement amongst co-basin states on trans-boundary fish conservation priorities that reflect ecological management objectives for sustainable use and conservation of native and endemic species;
- Transboundary Diagnostic Analysis and development of a Strategic Action Programme;

- In-depth analysis of key environmental stress, pressures and impacts in the basin;
- Identification of ecological quality objectives for the basin, and development of mitigation measures;
- Enhancing transboundary cooperation in Prespa Lakes basin water management;
- Water/watershed management plans of the three states to incorporate regional/transboundary considerations

5.6 Wastewater management

Wastewater management has been a long-time issue for the region and also a concern of many studies (Naumovski, 2012). This concern has been solved, when the wastewater treatment plant has been put in work in December 2014. Before its functioning, the situation of the water management in the Prespa littoral state as stated below (McIntyre, 2008)

Throughout the years, the Prespa Lake have been less well scientifically researched than Lake Ohrid, and such studies as having examined Prespa Lakes system have tended to focus on how much water it contributes to Lake Ohrid, even though a number of studies have been conducted on the unique hydrological and ecological system of the Prespa-Ohrid drainage basin. Therefore, it is not entirely clear how much water loss of the Prespa Lake is due to human activities, including agricultural irrigation and the abstraction of groundwater, and how much due to natural conditions, such as geological or climatic changes (including evaporation). Additionally, it is not clear to what extent this is due to decreasing water levels or pollution from agricultural run-off and inadequately treated wastewater is the occurring eutrophication. Similarly, despite the ongoing granting of fishing concessions and some illegal fishing, there is no systematic monitoring of fish populations or analysis of fish caught. Moreover, there is also a marked lack of data in respect of the socio-economic vulnerability of the Prespa communities should sectoral interests, such as tourism, fisheries, or agriculture, be adversely affected. For example, Prespa is the second busiest tourist destination North Macedonia after Ohrid with capacities as counted:

- Hotel Pretor, Pretor (around 254 guests in seasonal average);
- Hotel Kitka, Resen (around 40 guests in seasonal average);
- Auto camp Krani, Krani (around 3.298 guests in seasonal average);
- Private accommodation in villages (around 375 guests in seasonal average): Brajčino, D.Dupeni, Pretor, Slivnica, Ljubojno, and Stenje (UNDP, 2011).

According to these calculations, the current load from household sewage (without wastewater treatment) plays a significant role in the pollution of water bodies.

On the side of Prespa Lake that lies in North Macedonia there are several mid-size enterprises from eight industrial branches: food processing, poultry farming, textile, metal processing, wood processing, civil construction, ceramics, and chemical industry. These are:

- Food and Juices (DOO Swisslion Agroplod & CD Fruit – Carev Dvor, Vita Fruit Ltd.);
- Textile (DOO Hatex, DOO Krznoteks, DOO Tekstilprom);
- Chemical Industry (Ohis Prespa Plast AD & Delatask);
- Metal Processing (AD Algreta) - civil constructions (AD IGM Sloga);
- Poultry farm (Swisslion Agrar);
- Ceramics Production (Hamzali); and
- Wood Processing (DOO Interbrauk).

Wastewater collection system exists in Resen covering 95% of the population/ households and some of the surrounding villages (Jankovec 40%, Ezerani 95%, Carev Dvor 95%). The WW system in Resen is planned to be separate, however, only 25% of the stormwater network has been completed. The sewage network is burdened with high quantities of rainwater during rainfall. The number of SMEs in urban areas is also connected to the system.

Wastewater Treatment Plant “Ezerani” has been constructed near Ezerani village, 7 km south from Resen for treatment of sewage WW. The process at the WWTP in Ezerani is an activated sludge with subsequent aerobic sludge treatment. While the treated effluent is being directed into two maturation ponds in series, the stabilized sludge is directly diverted into the sludge drying beds. The design capacity of the WWTP is 12000 PE. The inflow of large quantities of rainwater in wet periods hamper the operation of the plant.

Table 5-1 Wastewater calculation for 20.792 people, based on the average load per person

Parameter	Unit	Value
Inhabitant	person	20.792
Q_{water} per capita	l/d***P**eople **E**quivalent (PE)	150
BOD_5	q/PE*d	60
COD	q/PE*d	110
TSS	q/PE*d	70
N (as TKN)	q/PE*d	8,8
P	q/PE*d	1,8
Calculations for wastewater quantity and quality		
Flow (Q)=(People*Qper capita)/1000	m3/d	3.118,8
BOD_5	m3/year	1.138.362
	kg/d	1.247,5
	kg/year	455.344,8
	mg/l	400
COD	kg/d	2.287,1
	kg/year	834.798,8
	mg/l	733,3
TSS	kg/d	1.455,4
	kg/year	531.235,6
	mg/l	466,7
N	kg/d	183
	kg/year	66.783,9
	mg/l	58,7
P	kg/d	37,4
	kg/year	13.660,3
	mg/l	12

Apart from the existing WWTP in Resen a number of treatment facilities have been constructed in the Prespa watershed area. However, few of the existing facilities are operational and, the facilities had been in duty only for a short time after construction. An exception is the WWTP in the tourist area of Otesevo. There exists a small WWTP in the village of Nakolec (not covering upstream villages of Brajcino and Ljubojno).

5.6.1 North Macedonia

The Water Law have been adopted in April 2008. The first phase of its implementation commenced with the entry into force on 4 July 2008 of Chapter III on planning and Chapter XI on organisational/institutional set-up, transferred responsibility for water resources management from the Ministry of Agriculture to the Ministry of Environment and Physical Planning, with full responsibility transferred in February 2010. Under this phase, the National Water Council has been established and has the responsibility for adopting the National Water Strategy. Adoption of the National Water Strategy is responsible for subsequent preparation of the Water Master Plan. In addition, four River Basin Management Districts (RBMDs) have been identified, which are administered by three River Basin Management Bodies (RBMBs). The RBMBs will replace the existing local-level water management organizations which are very heavily indebted. As regards RBMPs for transboundary basins, had to prepare a draft RBMP for the River Vardar basin, shared between North Macedonia and Greece, which runs the transboundary river basin management planning process and serve as a template for the development of further transboundary RBMPs, including one for the Prespa / Ohrid basin. The Water Law came fully into force on 1 June 2010 and facilitates full transposition of the E.C. Water Framework Directive and approximation with seven further E.C. environmental and water-related directives, including the Nitrates Directive, the Bathing Waters Directive, the Drinking Water Directive.

Spatial plans have already been adopted for most of the territory of North Macedonia, including the four RBMDs. Each spatial plan contains specific provisions in respect of the protection of natural and cultural heritage requiring that these values are taken into consideration in the preparation and adoption of RBMPs. In this. According to the Spatial Planning Law and the Water Law, all spatial plans require that the objectives of any RBMP be taken into account and given effect in spatial development policies and decisions. Conveniently, it appears that the area of the Prespa / Ohrid basin within the territory of the North Macedonia corresponds almost exactly with the boundaries of one of the provisionally proposed RBMDs.

The water quality monitoring system has been established for many years and monitors a range of parameters, including chemical and bacterial pollutants and metals. There is a need for this monitoring system to be coordinated with the development of the National Water Strategy and the Water Master Plan. Though the new Water Law assigns responsibility for particular activities to certain institutions, no funding for such institutions is prescribed under the legislation. Similarly, National Parks in North Macedonia are expected to be self-financing, which limits the range and extent of conservation activities in which they can afford to become involved. Also, fund-raising becomes a distraction and diverts resources and energy away from core conservation activities. As regards transboundary cooperation, the Water Law commits North Macedonia to cooperate with co-basin States in respect of transboundary waters. These provisions give legislative effect to requirements in respect of transboundary cooperation contained in the Recitals of the Water Framework Directive, to which North Macedonia has committed to approximate the laws of its Stabilization and Association Agreement with the EU. North Macedonia recognizes that the Helsinki Convention forms part of the environmental acquis, to which it is committed under the Stabilization and Association Agreement. The Government of North Macedonia is solidly committed to transboundary cooperation in respect of shared waters. For example, in 2004 it concluded an agreement with Albania relating to Lake Ohrid establishing the Lake Ohrid Watershed Committee (LOWC), which includes representatives of central government (including the Ministries of Environment, Agriculture and Foreign Affairs), local government, the scientific community, and the NGO community. The LOWC is assisted by a number of supporting bodies. including the Watershed Management Committee, the Monitoring Taskforce, and a joint Secretariat. It facilitates a high level of technical cooperation, including annual joint monitoring and analysis of the water quality, in respect of which the LOWC has adopted two Joint Protocols on Monitoring. In addition, North Macedonia was committed at the ministerial level to the 2002 draft tripartite Agreement on the Protection and Sustainable Development of the Prespa Park Area, prepared by the PPCC. There are earlier agreements related to transboundary water resources entered into by the former Yugoslavia with Albania in 1956 and with Greece in 1972, as well as a bilateral agreement concluded between North Macedonia and Greece on cooperation in the field of environment, but these have fallen into disuse and the institutional structures provided for thereunder have not entered into operation. On the other hand, The Ministry of Environment has established a technical working group on Prespa Lakes chaired and coordinated by the Deputy Minister for Environment. The establishment of this working group certainly helped to facilitate transboundary cooperation and communication in respect to the protection of the Prespa Lakes ecosystem.

5.6.2 Greece

Under the previous legal regime (1987 Water Law), responsibility for water resources management in Greece has been fragmented, with the Ministry for Development having responsibility for issues of water quantity and the Ministry of Environment and Public Works having responsibility for issues of water quality. Under the 2003 Water Law (Law 3199/2003), all responsibility for water passes to the Ministry of Environment and Public Works, which has established a new body, the Central Water Agency (CWA), to take overall responsibility for water policy. However, though the 2003 Water Law is intended to transpose and facilitate the implementation of the E.C. WFD, it appears that the constitutional basis of the CWA remains somewhat unclear and that it suffers from a lack of capacity pending the transfer of staff from the Ministry for Development. The Ministry of Development has commenced the process of preparing Water Management Plans (WMPs), but this has not been carried out exactly in accordance with the requirements of the E.C. WFD. For example, the draft WMP for the region of the District of Western Macedonia is incomplete as it includes a description of water uses but contains no program of measures and says little about transboundary water management. At the regional level, Regional Water Directorates are established under the chairmanship of the General Secretary of the Region, which has a key role in the implementation of the WFD. Currently, the Regional Water Directorate for Western Macedonia is working with old water management plans but in 2014 the new Water Management Plan for the District of Western Macedonia has been adopted, which facilitate the designation of river basin districts, identified on the basis of the requirements set out in the E.C. The plan (Hellenic Republic Ministry of Environment, Energy and Climate change special secreteriat for water project, 2014) defines the following:

» River Basins: The River Basin District of Western Macedonia according to Decision No. 706/16.7.2010 of the National Water Commission (Official Gazette B '/ 1383) includes two (2) River Basins:
  - Prespes (GR01), with an area of 1.210 km^2
  - Aliakmonas (GR02), with an area of 12.410 km^2.

» Administrative status: Water District GR09 is attached, for administrative purposes, to the Region of Western Macedonia in Greece of the Decentralized Authority\Water Directorate of Epirus - Western Macedonia (65,1%) and the Region of Central Macedonia of the Decentralized Authority\Water Directorate of Macedonia –Thrace (33,1%). Parts of the Water Basin District of low hydrological importance, belong to the Regional Units of Epirus (0,4%) and Thessalia (1,4%). The Water Basin District of Western Macedonia includes the Regional Unit of Florina, and almost the entire Regional Units of Kastoria, Grevena, Kozani, and Pieria, as well as significant parts of Imathia and Pella. The permanent population of the River Basin District of Western Macedonia (GR09), based on the 2001 census amounted to 589.525 inhabitants and reached 574.911 inhabitants, in accordance to the 2011 census, indicating a total decrease of 2.5%.

» Land Uses: The largest part of the River Basin District of Western Macedonia is covered with forest (56,37%), while agricultural land covers a significant part of the River Basin (39,95%). Artificial land accounts for 2,17% which is distributed among urban areas (1,09%), Industrial and Trade Zones (0,21%), Transport Networks (0,12%) and Mining and Mineral Sites (0,76%). Wetlands cover 0.53% of the total area and water surfaces 1.98%

» Major water uses: Water uses are distinguished in water supply, irrigation, livestock, industry as well as Energy Minerals extraction and thermoelectric power plant cooling in the Water Basin District. The total annual demand for all uses is about 1.191 hm3. The dominant water use in the River Basin District of Western Macedonia is irrigation with a consumption of 937 hm3 (79%), followed by water supply, with 141 hm3 (12%). Livestock contributes to the total demand with consumption of 9,3 hm3 (1%) and industry 8,5 hm3 (1%). Finally, 19,6 hm3 (2%) are used for energy minerals extractions and 75 hm3 (6%) are used for the cooling of thermoelectric power plants. Total annual abstraction from surface water bodies is estimated at about 574 hm3 (~ 48% of total annual demand), out of which 357 hm3 (~ 30% of total water abstraction) are used to cover the need for irrigation (293,2 hm3) and water supply (63,4 hm3) of the neighbouring Water District of Central Macedonia. Water needs of approximately 616 hm3/an (~ 52%) are covered with abstractions from ground waterbodies in the Water Basin District of Western Macedonia.

Under the new Water Management Plan for Western Macedonia, Greek Prespa / Prespa Park constitutes a single river basin district. The Water Management Plan consists mainly of measurements, targets, and objectives, and data on the state of waters, levels, and nature of water uses, the water available, and waters allocated. It is used by the Regional Water Directorate as the basis for issuing permits in respect of water pollution and water abstraction. While some data and studies may be collated by the Regional Water Directorates, other data are collated by the Central Water Agency, which has overall responsibility for compiling all such data and making it available to the Regional Water Directorates in order that they can prepare River Basin Management Plans on the basis of such data. The Central Water Agency has overall responsibility for water policy under the 2003 Water law and provides Regional Water Directorates with a format/template, to which the River Basin Management Plans have to correspond. The Regional Water Directorates retain legislative responsibility for the adoption of RBMPs but, as some RWDs were making poor progress in this regard, the CWA has stepped in to ensure effective and consistent implementation of the WFD. Also, it is recognized that there exist wide discrepancies between RWDs in terms of the capacity to prepare RWMPs, with the RWD for Western Macedonia among the less well resourced. The CWA has very recently issued guidance to RWDs on effective WFD implementation having regard to local conditions.

In relation to Prespa waters, the key institutional body is the Management Body for Prespa National Forest, which includes a Wetland Management Committee which makes decisions in respect of the water levels for Mikri Prespa. The wetland Management Committee provides evidence of cross-sectoral and inter-ministry coordination as it includes representatives of the Society for the Protection of Prespa (SPP), of the Regional Water Directorate for Western Macedonia, which operates under the authority of the Ministry for Environment, and of the Management Body for Prespa National Forest, which operates under the authority of the Ministry for Development. The targets for maximum and minimum water levels in Mikri Prespa are agreed with all stakeholders, taking account of a range of needs, including human needs, agricultural irrigation, and environmental/ecological requirements. The Management Body for Prespa National Forest is also engaged in a plan to purchase/expropriate a number of littoral fields/sites in order to restore ecologically important wet meadows.

A system of monitoring exists in Greek Prespa, with samples collected in Megali Prespa every three months from three points and from border points in the middle of the lake, and samples collected every three months from two points in Mikri Prespa. The samples are analysed for a range of organic compounds and toxic wastes by the Management Body for Prespa National Forest/Prefecture of Florina, who report to the Ministry for Environment and the Ministry of Foreign Affairs in Athens. However, there has been no formal mechanism for sharing this data with the other littoral States, though informal communication takes place through SPP. There is an acknowledged need for early exchange and efficiency of such information, early notification of problems arising, and early and proactive cooperation, in order for the littoral States to be able to take effective mitigating measures. It is also accepted that more monitoring stations are required at strategic points throughout the lakes and that better equipment and infrastructure would improve monitoring significantly.

In respect of fisheries, there are licensed fishermen/enterprises in Greek Prespa, who may fish all year round except for a 40-day closed season which corresponds with the spawning season. The closed season is normally agreed at an annual meeting with the relevant authorities for the other littoral States but no such meeting has been held in the past years on account of the difficult political situation that existed between Greece and North Macedonia. There are no restrictions as to ‘total allowable catch’ but restrictions to apply to professional fishermen as regards the size of fish taken. These restrictions do not apply to those fishing for sport/pleasure. The management of fisheries is the responsibility of the Agriculture Department of the Prefecture of Florina but there are no dedicated full-time staff or resources allocated to this function. Though the general state of fisheries is regarded as quite good, there is no established process for monitoring fisheries and the authorities rely on fishermen to report any problems. No such problems have been reported in recent years.

As regards agricultural practices, progress has been made in the last years in respect of the management of the use of fertilizers and related nutrient run-off. There has been a significant increase in recent years in the use of drip-irrigation for bean production and there is a plan to extend this practice to all bean production over the next few years. There has also been an increase in organic farming practices. Generally, the Greek authorities do not perceive there to be any significant tension between the existing bean farming and the ecological requirements of the Prespa Lakes system.

In respect of water pollution caused by untreated wastewater, the Greek have built wastewater treatment plant. The lack of waste water treatment infrastructure which corresponds to international / European standards in the other littoral States has been perceived as a problem by the Greek authorities.

A number of threats to the Prespa ecosystem are presented by activities carried out in Greek Prespa. For example, the excavation of sand from the isthmus presents a risk that the isthmus might be washed away due to hydro-pressure, as Mikri Prespa is 10 metres higher than Megali Prespa. Also, the building of small hydropower stations in the Prespa basin has been discussed on occasion.

The Greek authorities would appear to be involved in transboundary cooperation on an ad hoc basis. For example, a meeting of the Greek / Albanian Bilateral Commission on Transboundary Waters has been convened by the Greek Ministry of Foreign Affairs to discuss management of the Devoli River. Clearly, refurbishment of the existing irrigation canal could cause significant silting up of Mikri Prespa, as it has done in the past. Also, the country cooperates with Bulgaria, as an E.U. Member State, in respect of transboundary waters. Therefore, Greece would appear to be more prepared to enter into arrangements for bilateral cooperation than trilateral cooperation. Greece has signed an agreement for trilateral transboundary cooperation in respect of Prespa facilitated by the Prespa Park Coordination Committee (PPCC). In respect of Prespa, it would require data on meteorological conditions, water levels, groundwater resources, point and diffuse pollution sources, etc. from each of the littoral States.

5.6.3 Albania

The Water law od 2008 replaced the previous legal regime created by Law 80/93 on Water Resources. The Water Law has been prepared pursuant to Albania's pre-accession commitments and is facilitates full transposition and implementation of the E.C. WFD. Responsibility for water resources management has already been transferred from the Ministry of Public Works and the Ministry of Agriculture to the Ministry of Environment, but some uncertainty existed in relation to the allocation of key functions. The ultimate responsibility for water policy rests with the National Water Council, appointed and chaired by the Prime Minister.

Six River Basin Districts have already been identified and designated under Albanian law but the Water Law of 2008 facilitates the functioning of the River Basin Authorities in accordance with the requirements of the WFD. Each River Basin Authority is headed by the Prefect of the relevant Region and has representation from local authorities and the business community. The Semani River Basin Authority, which includes the area of Albanian Prespa, is chaired by the Prefect of Elbasan. Therefore, the River Basin Authorities enjoy considerable political and administrative authority. The River Basin Authorities have responsibility for administering the utilisation of water resources, some water quality, and environmental issues, the excavation of aggregates, etc. In discharging their functions, they must cooperate closely with the Regional Directorates of Irrigation and Drainage. The area of Albanian Prespa falls within the Semani River Basin District. The Law from 2008 is based on the National Water Strategy, implementation of which has not commenced 10 years after its adoption.

However, somewhat confusingly, the Albanian Prespa National Park Management Committee comes under the management of the Forestry Directorate of the Regional Council of Korce, and has responsibility for all aspects of a 5,000 hectares area of land and water, including the management of water resources, forestry resources, etc. Similarly, fisheries are managed by the Directorate of Fisheries, under the Ministry of Environment. Likewise, cultural amenities are the responsibility of the Ministry of Culture, which currently permits tourists to visit certain sites against the wishes of the Prespa National Park Management Committee, due to nature conservation concerns. Therefore, there is obvious potential for conflict among these various agencies.

Water quality issues in respect of transboundary waters are the responsibility of the Regional Environment Agencies / Inspectorates.

As regards transboundary cooperation, there had been an international agreement between the former Yugoslavia and Albania relating to cooperation on shared waters, but this arrangement has fallen into disuse. The Albanian Vice-Minister for Environment has sought to reactivate and renew the bilateral process for cooperation regarding the water management with North Macedonia in 2007. The Greece/Albania bilateral commission on transboundary waters met in November 2007 to discuss the Devali River. Albania favours the conclusion of two separate bilateral agreements with Greece and North Macedonia, which are covering all transboundary water management issues arising. Albania envisages the initial establishment of informal bilateral commissions, which coordinate with a body such as the PPCC over issues relating to Prespa, and that representatives of the PPCC participated in each commission.

Since 2001, Albania has developed and circulated model draft agreements to the two other littoral States, but Greece suggested that it would be better to first establish a commission to develop an agreement on the basis of its functions and experiences. One difficulty with this approach is that the Greek/Albanian Joint Commission has no dedicated funding. The 2001 draft agreement currently serves as the basis for negotiations with other neighbouring States, including Bosnia Herzegovina and Montenegro. Therefore, a total of three bilateral commissions exist in theory – Albania/North Macedonia, Albania/Greece, Albania/Montenegro – but, although members have been nominated, they have not been functioning in the time being. The Albania/Greece joint commission has met once, in November 2007, in relation to the Devoli River. Unfortunately, there is a severe shortage of personnel in the Ministry of Environment, including a mere three people in the Water Department, to assign to bilateral/trilateral cooperation initiatives.

Increased agricultural production in the vicinity of Albanian Prespa is contributing to the nutrient loading of Megali Prespa. Also, since 1990 unregulated tree felling and a lack of regeneration of forests have impacted the waters of Megali Prespa, though the position has improved somewhat since 1999. In recent years fishing has been regulated quite effectively in Albanian Prespa.

6

Educating tomorrow’s water managers: Experiences from regional student workshops

6 Educating tomorrow's water managers: Experiences from regional student workshops

by Yiannis Xenidis

6.1 Goals of educational activities

The developments both at the state as well as the European levels in terms of policies and regulations particularly applied for water management or in broader contexts that inherently involve water management, as well as the geographical conditions that require cross-border cooperation for water resources, are motivators for effective and substantial collaborations. Achieving them in the long-term requires an aligned targeting of goals, the respective commitment to these goals, a mutual understanding of the limitations and problems at each border side, and a mutual effort to overcome such limitations. Additionally, an insight of the existing background in terms of knowledge and technological preparedness along with the experience of previous collaborations in the same, similar, or other fields are also factors contributing to effective cross-border cooperation.

The creation and maintenance of the described context is substantially supported by the continuous efforts at the first stages of the careers of individuals that will contribute to and manage these collaborations through the different roles they may assume in the future as designers, constructors, operators, regulators, promoters, politicians, etc. Educating these individuals should include in situ collaboration, where the anticipated multifaceted collaborative culture should be formed and tested in real conditions. This chapter presents the designing, execution, and experiences of a series of educational – scientific workshops that took place between June 2017 and April 2019 aiming at creating a group of informed scientists in the field of water management with the potential to support in the future in various ways and at various levels the cross-border cooperation on the management of shared water resources.

Organizing educational activities

Three scientific-educational workshops were organized by the Schools of Civil Engineering, Aristotle University of Thessaloniki and Faculty of Mechanical Engineering, University of Ss Cyril and Methodius under the auspices and with the financial and logistical support of Konrad-Adenauer-Stiftung and Wilfried Martens Centre for European Studies institutions. All of them were located at close distance to water and wastewater management facilities of transboundary regions and water resources aiming at facilitating educational visits to such facilities. More specifically the three workshops were organized:

1. In November 2017 in the city of Dojran close to the lake Dojran/Doirani and the wastewater treatment facilities of Gevgelija and Kilkis.
2. In April 2018 in the city of Bitola close to the wastewater treatment facilities of Resen and Florina.
3. In April 2019 in the city of Ohrid close to the wastewater treatment facilities of Vranishta (Struga).

The workshops were addressed to an equal number of senior students and instructors from both countries, thus achieving a balance of the number of representatives in the group in terms of nationalities. Gender equality in the group's formation was also considered and, therefore, the overall number of students (30) was equally comprising males and females. Most importantly all students had a relevant knowledge background to the topics of water and wastewater management, however, in the context of different disciplines as they were coming from different schools of engineering, namely civil and mechanical. Based on the above, the overall design of the workshops' teams allowed for the addressing of various perspectives based on individuals' views and interdisciplinarity.

The workshops were carefully designed also in terms of the applied educational approach that could lead to the achievement of the goals set. This approach is presented in Section 6.2.

6.2 Educational Approach

Achieving long-lasting and profound impact is best served when experiential conditions are involved. Considering the multiple goals targeted, and the multifaceted workshops' nature, the outline of the adopted educational approach is depicted in Figure 6-1.

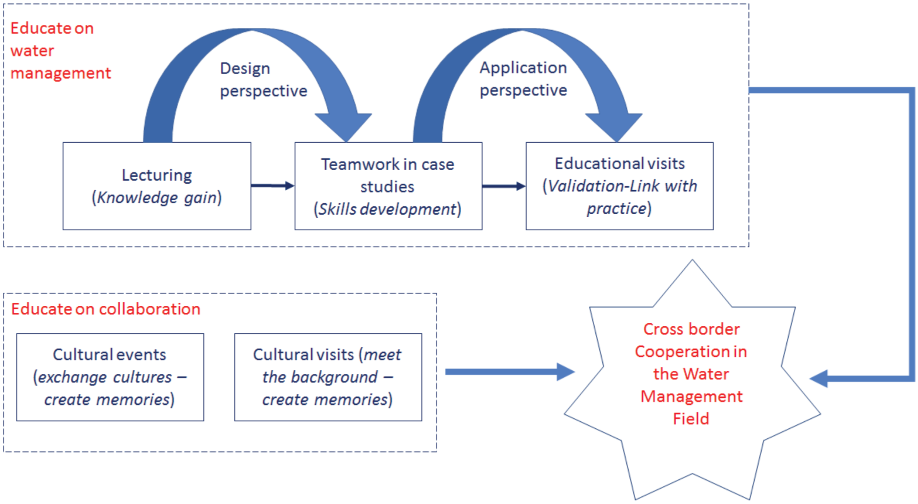


Figure 6-1 Outline of the educational approach

As shown in Figure 6-1, the educational approach was designed and applied to be equally inclusive of specific knowledge on the scientific field of water management and of creating the conditions for a collaborative environment wherein scientists coming from different disciplines and neighboring countries can work together towards solving common problems with multiple effects in life. This approach was deemed suitable for achieving the goals set, and its adoption was successful, as proven by the outcome presented in Sections 6.3 and 6.4 of this chapter. A more detailed presentation of the applied educational tools is provided in the section below.

Educational process

The original design of the educational process took place prior to the first workshop that was held in November 2017. Designing this first workshop was a collaborative activity by the participating staff of the organizations that organized this series of workshops. The final workshop's program was structured as shown in Table 6-1.

Table 6-1 Workshop's structure

ACTIVITY	GOAL TARGETED
1. Welcoming lunch and addresses (all)	Settlement, useful tips and framework
2. Ice breaking activity (all)	Team forming
3. Introductory lecture (all)	Context formation
Workshop's first topic: 4. Lecture (all) 5. Teamwork (two workgroups) 6. Presentation of results (all)	Education on water management: Major transboundary resources
Workshop's second topic: 7. Lecture (all) 8. Teamwork (two workgroups) 9. Presentation of results (all)	Education on water management: Local transboundary resources
10. Cultural event (Dinner, Party)	Cultural exchanges – Personal acquaintances
Workshop's third topic: 11. Lecture (all) 12. Teamwork (two workgroups) 13. Presentation of results (all)	Education on water management: Major facilities
14. Certificates awards	Team reward
15. Cultural visit	Cultural background
16. Educational visit	Link of provided knowledge with practice

This program has been applied in all three workshops in the same manner after some minor adaptations that were deemed necessary based on special conditions met during the workshops. The formation of a firm program that was recurring allowed the instructors to familiarize themselves with the potential difficulties that the students could face. This, in turn, allowed the instructors to focus on these particular difficulties and adapt their approach towards supporting the students to overcome any problems.

As Table 6-1 shows, the education approach depicted in Figure 6-1 was implemented through switching techniques that allowed a multifaceted and intense educational process that was pursuing simultaneously both knowledge provision and collaborative environment creation. The idea of creating modules relevant to various levels of water management (local-national) coupled with a holistic analysis of the policy, needs, and infrastructure issues allowed a straightforward presentation of the main issue under discussion in a simple, effective and attractive manner that created a strong impact for students in a short period of time.

The educational techniques aimed at providing the knowledge and skills backgrounds for managing water resources were the following:

Lectures

Traditional lecturing in a single group of students in the English language provided the theoretical background of each addressed topic in the context of water management. The lectures included the usual interaction between the audience and the instructor through Questions and Answers. Figure 6-2 and Figure 6-3 present two instances of lecturing activities.

Figure 6-2 Lecturing in Dojran's/Doirani's Workshop (November 2017)

Figure 6-3 Lecturing in Bitola's Workshop (April 2018)

Collaborative teamwork

One of the most critical educational activities was the collaborative teamwork of students in the context of each topic previously analyzed and discussed in the context of the relevant lecture. The specific issues that the students had to work on in three groups equally structured in terms of gender and nationality and comprising around 10 students each are presented in Section 6.2.2 along with the outputs of the teamwork.

Several details have been considered to create a framework for a fluent collaboration among students, including:

- » The use of portable devices, such as laptops and mobiles that allowed for:
    - instant and concurrent access to Internet sources,
    - rapid files-sharing among group members, and
    - moving around space with the equipment in hand for creating smaller groups of works, and expediting guidance provision from the instructors (see Figure 6-4 and Figure 6-5).

Figure 6-4 Collaborative teamwork in Dojran's/ Doirani's Workshop (November 2017)

Figure 6-5 Collaborative teamwork in Ohrid's Workshop (April 2019)

» The setting of the workspace (see Figure 6-6 and Figure 6-7) that allowed for:
  - intense group work among students
  - facilitating the overcoming of communication issues between students from different countries,
  - direct and unhindered communication that fostered collaboration among students.

Figure 6-6 Guidance provision/Intense teamwork in Dojran's/Doirani's Workshop (November 2017)

Figure 6-7 Guidance provision/Intense teamwork in Bitola's Workshop (April 2018)

Educational visits

Another critical educational activity was the visit to wastewater treatment plants that provided the necessary link between the scientific, theoretical approach and the applied practical solutions on the field. These visits validated the results of the analyzed case studies during the workshop or revealed shortages in applying design solutions in reality. The observations made on functional facilities and the briefing and discussions with the experienced operating staff of these facilities were valuable inputs in the context of a holistic educational approach to water management topics. Figure 6-8 and Figure 6-9 present two instances of educational visits in wastewater treatment plants.

Figure 6-8 Visit in Kilki's Waste Water Treatment plant (November 2017)

Figure 6-9 Visit in Florina's Waste Water Treatment plant (April 2018)

The cultural techniques aimed at creating the conditions for an effective collaborative environment among students and staff were the following:

Ice-breaking activities

At the beginning of each workshop, an ice-breaking activity aiming at encouraging participation and mental relaxation was deemed necessary as a first step towards establishing a collaborative environment among students. Both moving activities (e.g., blobs and lines), and small group speaking activities (e.g., three things in common) have been applied (see Figure 6-10 and Figure 6-11). Based on the general evaluation, ice-breaking activities managed to encourage bonding and smooth transition to the workshop's sessions.

Figure 6-10 Ice-breaking activities in Dojran's/ Doirani's Workshop (November 2017)

Figure 6-11 Ice-breaking activities in Bitola's Workshop (April 2018)

Cultural events

Additionally, to the workshop's working program typical cultural events, such as dinners and parties were organized to allow for both cultural exchanges (e.g. cuisine, music) as well as creating a more relaxed atmosphere wherein the workshop's participants could socialize, extend their understanding and create feelings for their collaborators. Figure 6-12 and Figure 6-13 provide two instances of such events.

Figure 6-12 Socializing at Bitola (April 2018)

Figure 6-13 Lunch at Vevcani (April 2019)

Cultural visits

Cultural visits to natural, historical, and cultural sites were organized aiming at providing the participants an insight into cultural heritage and supporting a deeper understanding and knowledge of the cultural background between neighboring countries. Figure 6-14 and Figure 6-15 provide two instances of such events.

Figure 6-14 Guided tour to the city of Bitola (April 2018)

Figure 6-15 Vevcani Springs (April 2019)

6.3 Workshops' results

As shown in Table 6-1 each workshop focused on case studies at both national/transnational levels. Each case study was presented and discussed in advance (lecturing activity) to foster the creation of a minimum common knowledge background. Then a number of specific tasks relevant to the presented case studies were assigned to the students who split in parallel working groups. While the tasks were similar for all groups, each group was working individually to perform the tasks in each own way with respect to the focus on the proposed solutions and management structure during the tasks' performance. The final results from each group's work were then presented and discussed in front of all the participants. This last phase of the educational process allowed for the evaluation of the presented ideas and solutions and a further discussion and exchange of knowledge and opinions on the issues under study. Sections 6.3.1-6.3.4 present the summarized results from the students' teamwork for each case study in each workgroup, in all workshops.

6.3.1 The Vardar/Axios River Case Study

Context and preparation

The Vardar/Axios river (Figure 6-16) case study was studied in the context of the first workshop organized in Dojran in November 2017 and the third workshop organized in Ohrid in April 2019.

Figure 6-16 Vardar/Axios River

1) The module focused on the situation and possibilities for joint cooperation in coping with the challenges of water management at the national transboundary level and, especially, the case study of the Vardar/Axios River.

A detailed presentation of the case study was articulated among two pillars, namely presenting the river basin and analyzing its importance through a DPSIR (Drivers-Pressures-State-Impact-Responses) analysis. The river's basin presentation included information about the geography, inflows, and uses. The DPSIR that followed assessed the socio-environmental developments in the basin's area due to the interdependent economical drivers and pressures with the Vardar/Axios river. This strong interdependence, which captures the two-way driving forces for using a natural resource in a sustainable manner has been presented through the DPSIR analysis on the areas of agriculture, cattle breeding, shellfish & mussels' production, industry, energy, and water supply.

Following this presentation, a number of issues were set for the students to investigate and discuss. These issues were the following:

1. What is the extent of the current wastewater treatment network? This topic sought to investigate the needs for effective wastewater management in comparison with the situation as shaped through existing facilities and the served areas and population from them, the type of waste and extent of treatment, and other similar properties.

2. What is the current background for wastewater treatment in both countries? This topic sought to motivate in obtaining an insight into the framework wherein actions on wastewater management could take place. It was indicated that this framework should be investigated in terms of legal and institutional aspects, relevant educational and cultural dimensions, etc.

3. What is the extent of cooperation between the two countries with regard to infrastructure? This topic sought to investigate the level of existing cross-border cooperation through complementary infrastructures in terms of operation or frameworks and initiatives at national, regional, or European levels that promoted cross-border cooperation in the field of water management for the Vardar/Axios river.

Results

The students worked in parallel groups as described in Section 6.2.1. Following their investigation on the material that had been provided in the module's lecturing stage and on that found in other sources (mainly the internet), they finally presented their results concerning the discussed topics. These results could be summarized as the following:

» The network of wastewater treatment plants comprises an almost equal number of operating facilities at both sides of the borders, which are distributed on the land as shown in Figure 6-17 and Figure 6-18. However, a significant (taking into consideration the existing network) number of facilities with an even more significant population equivalent is under development on the river's northern part, which should be expected given the land coverage of the river's basin in North Macedonia (~ 83%) compared to the respective in Greece (~ 11%). These facilities are presented in Table 6-2.

Table 6-2 Planned waste water management facilities (P.E. in thousands of people)

Area	Skopje	Bitola	Veles	Shtip	Tetovo
P.E.	630	100	55	55	10

The processed wastewaters are mostly of the typical domestic type, despite the fact that there is a substantial part of them generated in industrial zones mainly in the Greek side. The extent of treatment varies as there are facilities that apply:

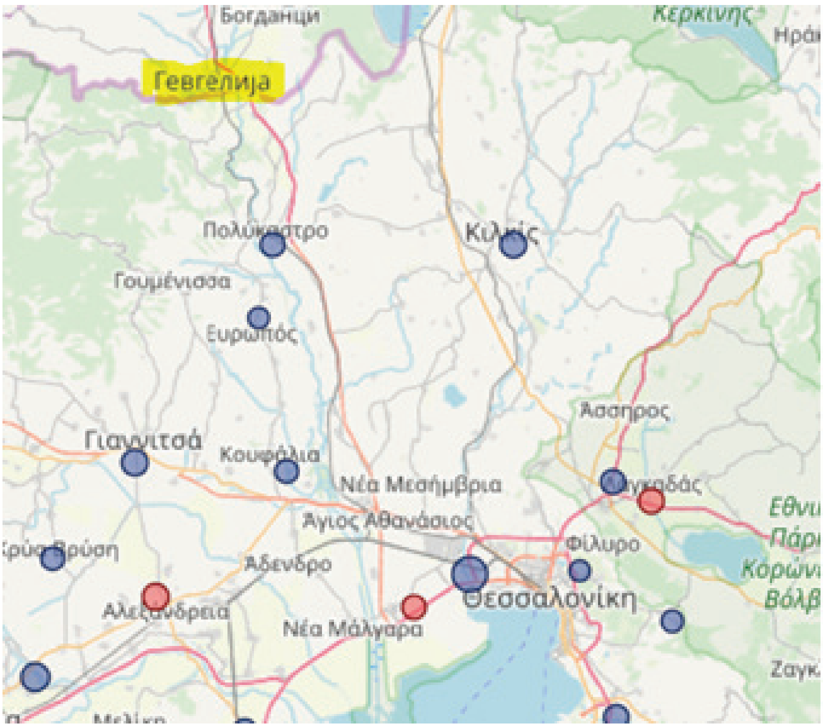


Figure 6-17 Waste Water Treatment Plants in the river's basin in Greece

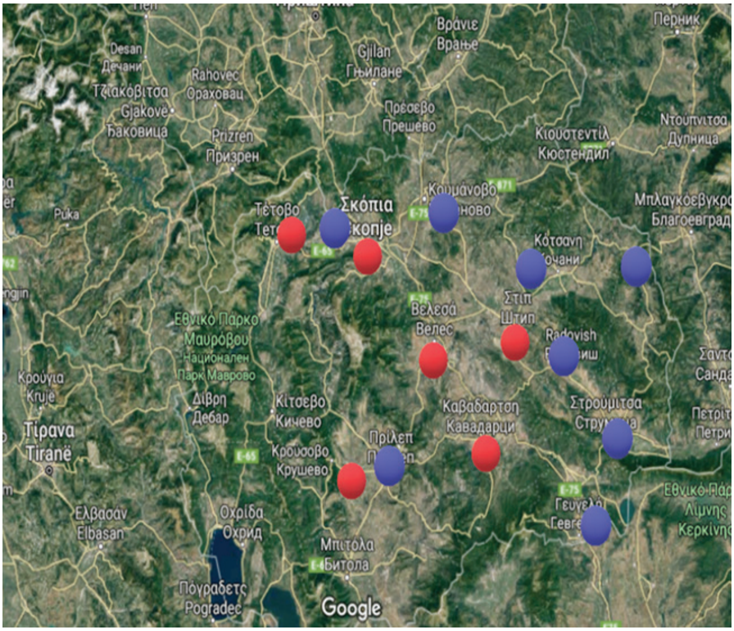


Figure 6-18 Waste Water Treatment Plants in the river's basin in Greece

- Anaerobic digestion of primary and secondary sludge, and mechanical dewatering (e.g. WWT in Kumanovo).
- Two-stage activated sludge, sludge reed bed treatment (e.g. WWT in Berovo).
- Pre-first, first, and second-grade treatment and biological and chemical decontamination (e.g. WWT in Polycastro).
- Pre-treatment and secondary treatment, chemical decontamination, UV disinfection, disk filters (e.g. WWT in Chalastra).

» The quality of the river's water is endangered and even diminished by several problems that exist in both sides of the borders. Such problems are:

- The excessive agricultural use that in many cases escapes control, thus resulting in over-pumping of underground waters along with the use of pesticides and fertilizers has an impact both to the aquifer's sustainability as well as the environmental conditions both across the river (nitro-polluted soil) and at its estuary in Thermaikos Golf (brackish waters in the coastal zone).
- The requirement for improved treatment of wastewaters from urban environments. Especially, the construction of a wastewater treatment

plant in Skopje is of utmost importance towards the substantial improvement of the water quality in the river. Additionally, complementary measures such as stricter controls to irrigation, unauthorized industrial and domestic uses of water, and solid waste management are required to improve the river's water quality.

» A potential reuse of cleaned wastewaters and byproducts as sludge is evident. This reuse could refer to urban use for fields and gardens irrigation, replenishment of surficial water, agricultural and energy use, and use in the construction industry as a composite for producing materials (e.g. mixed with clay for bricks production) or landfilling.

» The legal and institutional framework governing the management of the Vardar/Axios river is concise and clear and it mainly stems from the European Union's directives and several international conventions. However, it is unfortunate that no bilateral agreements exist, and the management is ruled by the general framework and the level of conformity to that in the two countries.

» The cross-border cooperation in the management of the Vardar/Axios river remains at very low levels. This reality could be considered as the result of a largely fragmented approach between the neighboring countries that may originate from the fact that the river is exploited at such levels in the upper part that renders it a resource of low capacity for the needs in the lower part. This in turn results in the lack of planning or investment in infrastructure for increased use of Axios river in Greece, hence, the lack of interest for closer cooperation. However, it is evident that in this way, a significant potential of exploitation of the Vardar/Axios river is lost and the resource is mismanaged.

  Positive steps towards the increase of this cooperation have been the several past and current projects that have received funding from national or European programs and investors that have contributed to the development of solutions and a cooperative environment on water management of the Vardar/Axios river. Such projects have been mentioned in previous chapters.

6.3.2 The Dojran/Doirani Lake Case Study

Context and preparation

The Dojran/Doirani lake (Figure 6-19) case study was studied in the context of the first workshop organized in Dojran in November 2017 and the third workshop organized in Ohrid in April 2019.

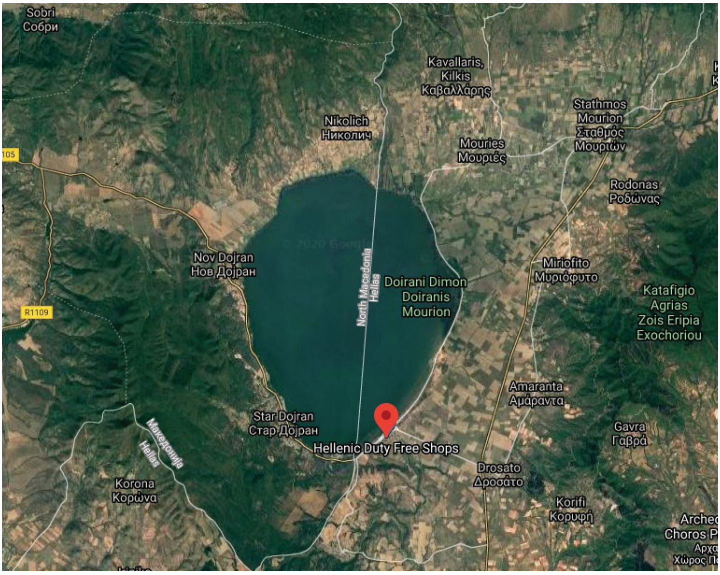


Figure 6-19 Dojran/Doirani Lake

The module focused on the situation and possibilities for joint cooperation in coping with the challenges of water management at the local transboundary level and, especially, the case study of the Dojran/Doirani Lake.

Following a detailed presentation of the lake that included the catchment area, the geographical setting, the standard pattern of weather conditions, the demographical data, the water reserves (surface and groundwater quantities, use, and quality), the environmental setting, and, finally, the governance context, the workshop's participants were asked to investigate the same questions posed at the national level only this time scaled at the local level close to the lake. It is worth mentioning that the identified issues for investigation were purposely identical for two case studies with completely different characteristics. The reasoning behind this approach was to manifest the similarity of the fundamental aspects, variables, and resolution or tackling methods and tools addressed in water management issues despite the obvious differences of settings and properties of the issues at hand.

Results

The students worked in parallel groups as described in Section 6.2.1. Following their investigation on the material that had been provided in the module's lecturing stage and on that found in other sources (mainly the internet), they finally presented their results concerning the discussed topics. These results could be summarized as the following:

» There is an existing network of facilities that requires a significant upgrade mainly from the western part. This network currently comprises: a) the wastewater treatment plants of Toplec (western part) and Kilkis (eastern part), b) three monitoring stations in Kilkis, one for the lake and two for groundwaters, c) automatic monitoring stations in Mrdaja and in Star Dojran from which mainly infrequent measurements are taken, and d) a meteorological station at Metaxochori. Infrequent groundwater measurements are also taken via piezometers in wells. Although operating for a long time (Toplec operates since 1988), the facilities in the western part are partially fulfilling their role as they process mainly springs' waters, which are a small percentage (20%) of the generated wastewater in the area. The processed wastewater is discharged to the Luda Mara and Anska rivers, while the unprocessed portion, which is the wastewater produced from domestic use is discharged into the ground through septic tanks.

» Several pressures to the lake's water reserves exist both of quantitative and qualitative nature. In terms of quantity, the main pressure on the lake's water levels is due to excessive irrigation for agricultural activities, mainly in the lake's eastern part. Until 2003 this pressure was coupled with the reduced restoration of water reserves due to reduced precipitation; however, this situation has been reversed after the construction of an irrigation system in the lake's eastern part and the increase of precipitation on an annual basis. In terms of quality, a significant concentration of chemical pollutants is observed mainly due to the disposal of unprocessed wastewaters from the residential and touristic facilities in the lake's eastern part. At the same time, the lake's ecosystem, which is of great ecological value (a designated "Wildlife Refuge", and a declared "Preservable Monument of Nature" for Oak trees and Fraxinus) is also pressured from tourism (famous area in the past for mud baths, mostly recreation in recent era) and illegal fishing and hunting.

» The maturity level for the lake's water management differs between the neighboring countries. In Greece, the lake is designated as NATURA 2000 site, thus water management is governed by well-defined and strict national and EU regulations and legislations. A management plan of the basin has been developed in the context of the Directive 2000/60/EC, which addresses environmental goals, economic analyses, and action measures to effectively manage the lake's water. At the same time, considerable ongoing efforts are made in North Macedonia to reach a similar level of maturity in management, mainly through a continuous revision of legislation, educational activities, and funded research programs.

» Effective bilateral cooperation for the lake of Dojran/Doirani remains an issue. Although historically there have been bilateral agreements and actions for endorsing joint efforts towards achieving an effective lake's water management, there is still a great potential that remains unexploited. While there is a constant exchange of information collected mainly from the monitoring stations, more efforts are required to reach a level of water management that will be governed by a fully aligned legal and institutional framework and applied by a complementary network of infrastructure from both sides of the borderline.

6.3.3 The Prespa Lake Case Study

Context and preparation

The Prespa lake (Figure 620) case study was studied in the context of the second workshop, held in Bitola in April 2018.

Figure 6-20 Prespa Lake

The module focused on the situation and possibilities for joint cooperation in coping with the challenges of water management at the local transboundary level and, especially, the case study of the Prespa Lake, a unique case of an aquifer shared by three states in the region.

The module comprised two steps. First, a detailed presentation of the lake starting from the catchment area, and sources (e.g. the special management plan of the Western Macedonia River Basin District in Greece for the sub-basin of Prespa) for retrieving data and information for the monitoring of the lake's ecological and chemical status. An extended reference was made to the existing cooperation between the neighboring countries that have resulted since 2000 to the establishment of the Prespa Park, which is a unique transboundary protected area and a Ramsar Protected Site. The international agreement for the foundation of the Prespa Park has set the ground for enhanced cooperation among the respective authorities in the neighboring countries concerning mainly environmental protection and preservation issues, including the protection against habitat degradation, and the exploration of methods for ensuring the sustainability of the aquifer. However, the most important goal was to render the Prespa Park a successful model of transboundary cooperation of water management in the region. The level of achievement of this goal, and the routes followed to reach that level as well as the remaining challenges for successful water management at the local transboundary level and, especially, regarding the Prespa lake were investigated by the workshop's participants at the second step of the workshop's module.

Results

The students worked in parallel groups as described in Section 6.2.1. Following their investigation on the material that had been provided in the module's lecturing stage and on that found in other sources (mainly the internet), they finally presented their results concerning the discussed topics. These results could be summarized as the following:

- The major uses are related to water supply and irrigation, with a total annual demand of around 90% and 7% respectively (the remaining 3% corresponds to livestock farming uses). The aquifer is strongly pressured from wastewaters that end up in the lake with great concentrations in sulfates, total nitrogen (nitrates and ammonia), and phosphorus, thus creating a hypereutrophic environment. It is worth mentioning that industrial wastewaters produced in the northern part mainly from food processing, chicken farms, textile, wood processing, chemical, metallurgy, and construction plants are flown unprocessed into the lake. A reduction of the resources reserves has been attributed mainly to dry periods and underground outflows to the neighboring lake Ohrid.

» The situation concerning wastewater facilities differs on the two sides of the border. In the northern part, the municipality of Resen is served by a sewage system that covers only 55% of the community, while only domestic wastewaters are processed in the wastewater treatment plant of Ezerani. Given that the plant has been designed for a P.E. that considers almost a double population in the area, it is evident that it significantly underperforms as it works for about 30% of its capacity. This underperforming is further amplified by the fact that a high volume of surface water enters the plant's treatment facilities. Last, the ineffectiveness of the wastewater treatment is further increased by the fact that industrial wastewaters produced mainly from food processing, chicken farms, wood processing, textile, chemical, metallurgy, and construction plants remain unprocessed. In the southern part, the situation is rather better as the municipality of Prespa is wholly covered by a sewage system, apart from a small village with individual disposals. The settlements in the region are underpopulated, thus no actual need for wastewater treatment plants exists; however, two artificial wetlands have been constructed to serve small settlements in the area.

» The early identification of the Prespa lake as a natural resource that requires protection and preservation has helped to create synergies and has supported actions both from the administration and non-governmental organizations in both countries. The lake's ecological and economic importance has been well recognized, thus leading to the establishment of special management bodies and plans for the sustainable use of the resource (e.g. Strategic Action Plan for the sustainable development of the Prespa Park). The respective EU directives and especially the specific directive for the Prespa Lake basin constitute a more robust framework for cross-border cooperation than in any other case of shared waters between the two countries. Given this background more synergies are required to the implementation of this framework and further enhancing it through the elaboration of: a) the existing environmental monitoring networks to joint ones, b) a joint basin management plan for the EU programming's period of 2021-2027, and c) a joint crisis management plan for emergency situations, such as extreme droughts, floods, etc.

6.3.4 Policies and Organizations for Cross-border Cooperation on Water Management

Context and preparation

The case study on developing infrastructures, policies, and bodies that could foster cross-border cooperation on water management was investigated in all three workshops. The idea behind that module was for the participants to transform the findings of the rest of the investigated case studies to appropriate suggestions of new infrastructure or maintenance of existing ones, as well as outlines of policies and management bodies for transboundary water resources. A different approach was required for this case study as the available tools to apply would not come from standard engineering fields but rather from management and policy-making areas. The selected tools were chosen for their simplicity to understand them and apply them as well as accurately interpret their results. For the prioritization of the environmental pressures of the given aquifer, the MoSCoW feature prioritization chart (see Figure 6-21) was used where the identified issues are prioritized in the following scale:

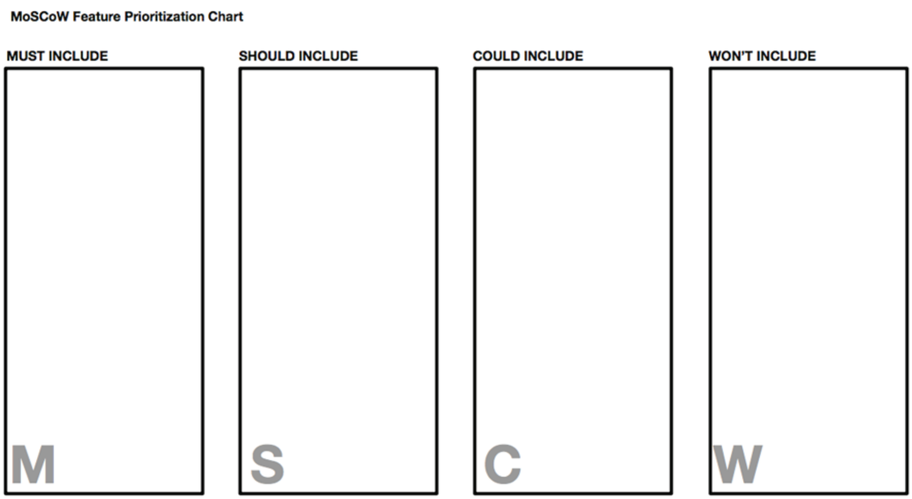


Figure 6-21 The MoSCoW prioritization chart

- Must include: Absolutely required to achieve goals
- Should include: Nice to have, but not critical
- Could include: An option but with additional issues to resolve
- Won't include: Not a part of the analysis

Once the environmental pressures were identified and prioritized, the suggested solutions (infrastructure, policies) were examined in terms of feasibility with the help of the TELOS model, which is presented in Figure 6.22.

Figure 6-22 The TELOS model for conducting a feasibility study

As shown in Figure 6-22, the TELOS model is named after the acronym of the aspects that a project should be examined for its feasibility. These aspects in more detail are related to:

» Technology. It is important to look at what kind of technology will be necessary to fully complete the project successfully.
» Economics. It is important to investigate the cost factors (e.g. total cost) of a specific idea and compare it to the estimated return value to determine whether the idea is worth undertaking or not.
» Legal. It is required to carefully note any current legislation that may affect a proposed project in order to understand what kind of impact this legislation may have on the success of the idea. Government bodies and relevant external regulatory bodies should be looked at, while prior commitments like internal policies should be considered as well.
» Operations. It is important to analyze the operations in order to determine the effectiveness of the project in solving the problem at hand or at accomplishing

the goals in mind. Such analysis addresses the availability of several people and agencies that will be involved and be needed in the whole project development process.

» Scheduling. The scheduling aspect of the project is the final stage of the feasibility analysis. It looks at forming a realistic time frame for project completion, and assists in assessing the viability of the idea as well.

Last, the profile of a potential organization for the transboundary cooperation on water management was identified through standard SWOT analysis.

Results

Concerning the environmental pressures that were identified on the water resources and their prioritization, an indicative MoSCoW chart as developed during the workshop is presented in Figure 623.

Must Include	Should Include	Could Include	Won't Include
Uncontrolled water pumping from the lake and wells (regarding Dojran Lake)	Low public awareness (solid waste dumping)	Pesticides discharge	Climate change
Not enough coverage by the sewerage system	Population growth	Uncontrolled fishing	
Industrial water	Uncontrolled water pumping from the lake and from wells (regarding Vardar/ Axios river)		

Figure 6-23 MoSCoW chart for environmental pressures on transboundary water resources

As shown in this example the students have focused on dealing primarily with engineering issues, while the further the pressure was from an engineering point of view, the less significant was considered for inclusion in the proposed policy. This is a very interesting finding as it confirms the fragmentation that exists in dealing with multifaceted projects and the pressuring need for interdisciplinary approaches for complex problems.

The suggested projects and policies for overcoming the pressures as prioritized in Figure 6-23 were the treatment of industrial wastewater for the case of the Vardar/ Axios River and the connection of individual households with the sewage system in the case of the Dojran/Doirani lake. The pre-feasibility analysis for each proposed solution with the use of the TELOS model is presented in Figure 6-24 and Figure 6-25. Although at a very high level and with several issues addressed with vagueness, the analyses shown in these figures constitute a first step that would be beneficial for a real preliminary feasibility analysis for the proposed projects.

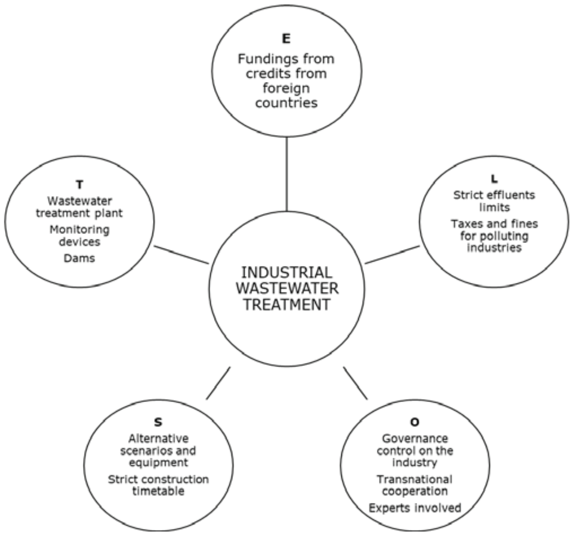


Figure 6-24 TELOS pre-feasibility analysis for industrial wastewater treatment plant for the Vardar/ Axios river

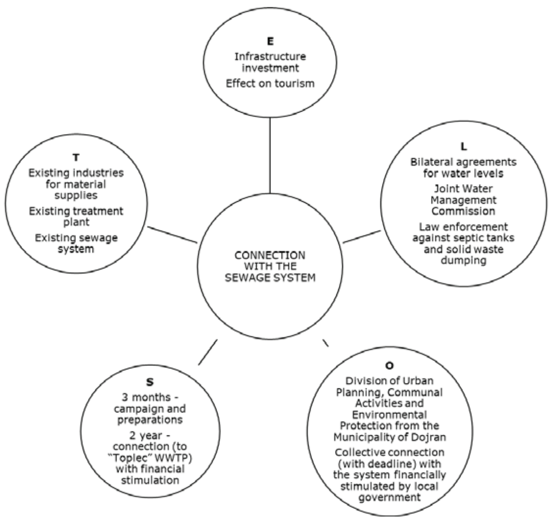


Figure 6-25 TELOS pre-feasibility analysis for connection with the sewage system for the Dojran/ Doriani lake

Concerning a potential organization for the transboundary cooperation on water management a collective SWOT analysis that addresses all the elements identified by the students is presented in Figure 6-26.

STRENGTHS	WEAKNESSES
» Engineering and consultant background » Academic support » Shared experiences between experts from both countries » Access to funds from the EU » Innovation	» No strong bonds between countries » Lack of cooperation culture » Different language
OPPORTUNITIES	**THREATS**
» Public support » Tourism » Funding from global organizations (UN) » Integration by both countries of the EU legislation and directives	» Different legal framework » Political turmoil in both countries » Controversial cooperation because of previous disputes » Lobbyists from polluting industries » Insufficient government funds for support

Figure 6-26 SWOT analysis for an organization for the transboundary cooperation on water management

As shown in Figure 6-26 such an organization would be expected to constitute a robust hub of knowledge and innovation for water management sharing experiences from staff and having satisfactory access to EU funds. Of course, several shortcomings would exist (at least at the beginning of its establishment) due to the lack of previous cooperation and the language obstacle. These shortcomings would have the potential to increase political reasons, and inconsistencies in the legal frameworks along with interventions from polluting industries overcome the opportunities for cooperation that emanate from economic activities, public support, and institutional need for compliance with the EU legislation and directives.

The successful establishment of such an organization would rely on steady and strong funding, societal awareness, academic support, and full implementation of the respective EU directives.

6.4 Evaluation and perspectives

Cross-border cooperation on water management is very significant for the cooperating parts for a number of good reasons. Should only one be highlighted that is the need and responsibility to deliver to the next generations at least the same quality and quantity of long-existing natural resources that have played (and still do) a central role in the development of human societies in the area. However, in order to successfully achieve that, a number of parameters of various natures (technical, institutional, financial, political, societal) need to be considered. A holistic approach to the management of transboundary water resources initiates from the cultivation of a synergistic culture between the involved parts in neighboring countries. This culture can be profound if elaborated through the education of the individuals that will be asked in the future to support the needed cooperation with multiple roles and from various positions. This education has to be multifaceted and should comprise all relevant aspects, including specialized knowledge, communication and cooperation skills, and managerial capabilities. The series of workshops that were presented in this chapter was an effort in this direction.

The success of the workshops is confirmed in many ways. First, a direct evaluation from the students who participated and asked through formal questionnaire evaluation surveys after each workshop has shown that:

» The main reason for participating was a professional interest in the workshops' topics, thus proving the understanding of the importance of transboundary and national water management and the professional perspectives that lie within the respective fields of activities.
» The workshops themselves were very satisfactory almost in all terms, i.e. the distributed material, the course topics, the instructors, and the duration and location of the facilities. What could be noted as a shortcoming was the little time given for discussion and feedback, something that shows a sincere interest in the workshops' topics.
» The workshops lived up to the expectations of the students, helped them to gain new knowledge, and motivated them to deal with the discussed topics more intensively in the future.

A second more indirect evaluation could come from the recorded outputs of the students' work in the various workshop modules. As it can be seen, these outputs are largely validated by a simple comparison both with the respective literature and relevant programs' outputs as well as with the realities faced in the field of transboundary water management for all the investigated case studies. Indeed, with minor deviations, the students – through the applied educational process – were able in a limited period of time to conceptualize, analyze, understand, and experience the complex issue of transboundary water management. Through their analyses and the educational approach, they collectively identified very accurately, and in an appropriate depth, the state-of-the-art, the sources of knowledge, information, and data, and the available tools to tackle specific problems for both countries and for all the cases that were investigated.

Judging from all the above, it becomes evident that the series of workshops that were presented in this chapter have been successful in achieving their goal, namely, to educate future water managers to cooperate on transboundary water resources. In this sense, the whole design and execution of these workshops could become a model for additional similar educational activities and for other applications in other fields where cross-border cooperation is required. It is reasonably believed that the implementation of this model could enhance a positive attitude and way of thinking towards synergies and cooperation and foster the ability to elaborate reasonably on relevant problems and decisions without exaggerating benefits or shortcomings. Furthermore, judging from the content faces of the workshops' participants as shown in Figure 627, it is reasonably believed that the implementation of the proposed model can create an effect in the long term that with appropriate multipliers can broaden the perspective in cross-border cooperation in any field of mutual interest.

Figure 6-27 Group picture from the visit to the Waste Water Treatment Plant in Florina (April 2018)

7

Summary

7 Summary

Until very recently, the water resources management of the Vardar/Axios River used to be a hostage of political disputes between North Macedonia and Greece that share the river basin. The identified problems on the water resources, such as the degraded water quality of the river in North Macedonia, were publicly known and accepted, however, the lack of political cooperation between the two countries didn't contribute to addressing these problems. Cross-border programmes and projects were limited and were mainly based on institutional and scientific cooperation rather than on specific cooperation agreements at the countries' level.

Currently, the resolution of North Macedonia's name dispute accelerated the accession process of the later into the European Union family. North Macedonia has achieved huge progress on the integration of the WFD into its national legislation, an issue of great importance since both countries sharing the Vardar/Axios river basin will have the same legislative framework, rules, and tools for the management of the water resources. Towards this direction, the formulation and enforcement of stringent regulations and standards, like those proposed within the WFD, will ensure that incoming wastewater and outgoing effluent within the Vardar/Axios River are of acceptable quality. Fully integrating wastewater management into the overall water management cycle requires establishing clear and enforceable regulation, with the allocation of appropriate financing supported by suitable, collaborative business models to build and operate the collection, treatment, and disposal systems; a concept that is also promoted within the WFD.

Almost all the past cooperation programs and projects between the two countries focused on the creation of an operative monitoring system of the quality of the water resources. Currently, the two countries have the perspective of creating common effective regulatory frameworks for water resources, infrastructure, and services. What is of particular importance is the political willingness for closer cross-border cooperation, and by following a top-down approach to coordinate the performance of responsible public authorities and their water operators.

Water resources management can have a significant role in climate change mitigation. Specific water management interventions, such as wetland protection, conservation agriculture, and other nature-based solutions, could enforce the mitigation at the basin-scale. Climate change adaptation strategies and plans at the river basin scale is a new thematic challenge. The two countries should seize the opportunity for common strategies since the new EU's funding programmes aiming at climate change adaptation with emphasis to be given in cross-border areas. Finally, to strengthen cooperation, the support of knowledge transfer and skills development while promoting education programs to assist in changing negative perceptions is a key issue. The series of regional students' workshops aiming at the cross-border cooperation in the water management field organized by the Ss Cyril and Methodius University and the Aristotle University of Thessaloniki, under the auspices of Konrad Adenauer Stiftung in Skopje and Athens, the Wilfried Martens Centre for European Studies and the UNESCO Chair INWEB, may be conceived as a cornerstone in promoting cooperation.

8

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