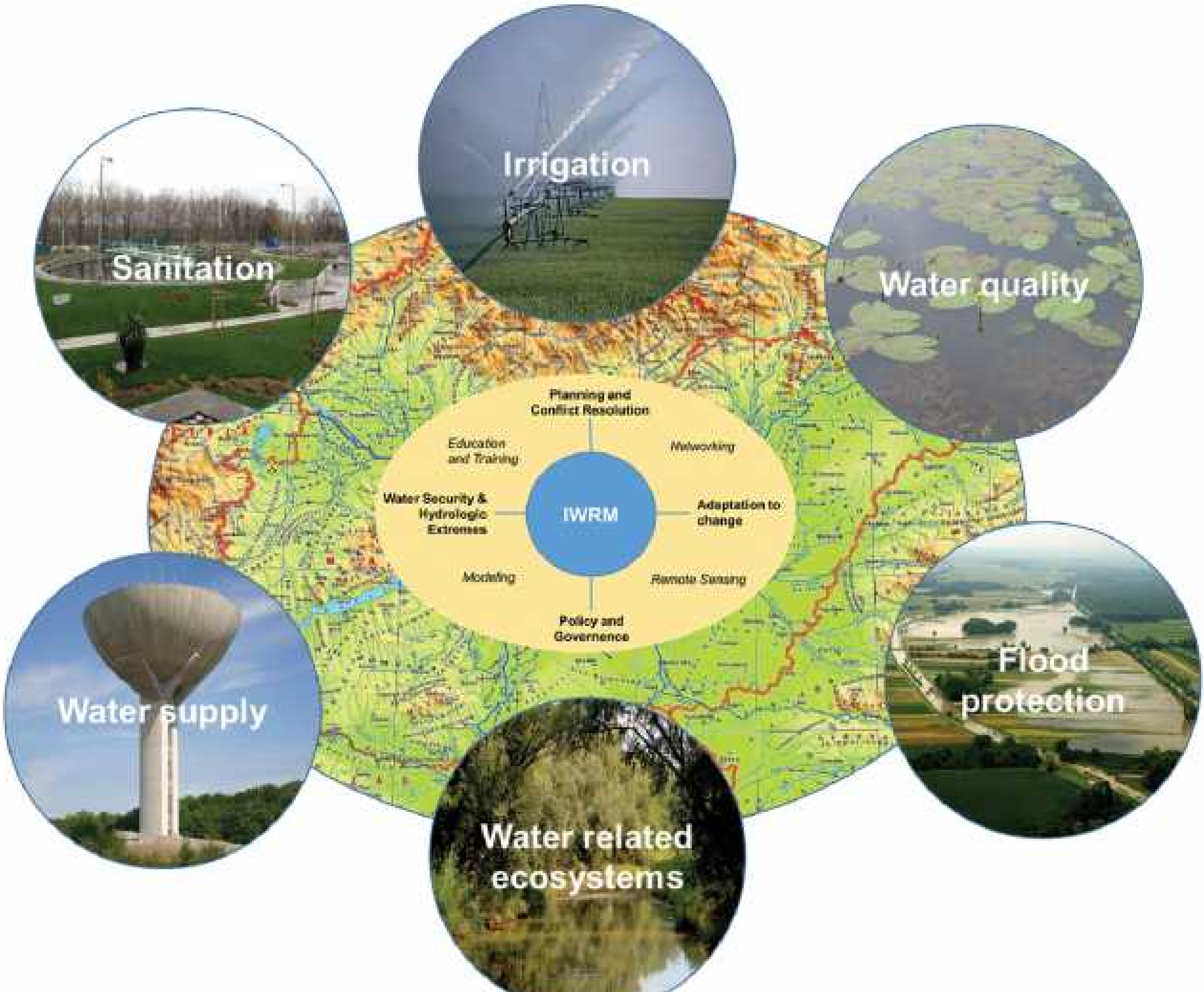
# HIDROLÓGIAI KÖZLÖNY

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# Hidrológiai Közlöny

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# Tartalomjegyzék




Címlapfotók:
Bal felső: Tóth Emese Vanda, Duna Múzeum Fotóarchívum
Jobb alsó és alul középen: Vizy Zsigmond, Duna Múzeum Fotóarchívum
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# The 100-year-old Hungarian Hydrological Society welcomes the participants of the Budapest Water Summit 2016

On 7 February 2017 will be the 100th anniversary of the foundation of the Hungarian Hydrological Society. Our Society is a social, scientific and professional association established to deal with hydrology and related sciences engaged in water related issues.

The objectives of the Society are to promote the development of the country, to facilitate the scientific and technical progress, disseminate scientific knowledge and share information as well as upgrade the knowledge of professionals working on different water related professional fields.

We consider that our tasks are in connection with water related professional fields: to spread the technical, natural and social scientific knowledge; to introduce the water science disciplines and their past as well as the results of the current scientific and practical trends; to promote the national awareness about the latest development efforts and their utilization; and to contribute to the international awareness of domestic results.

We foster and strengthen our international relations, the traditions of the water related disciplines. We pay attention to and keep the memory of the deceased outstanding professionals worked on various professional fields, as well as preventing and processing their scientific legacy. We also pay attention to the training of water professionals with developing and supporting their professional culture and fastidiousness. These goals are served by our major events, presentation seminars and publications.

Members of our Society are not only engineers, but there are also professionals who are dealing with water in many different disciplines, such as science teachers, geographers, chemists, physicians, biologists, ecologists, historians, economists, jurists etc., which situation - in the last century - was good for, in one hand, the expansion of engineering thinking, and on the other hand, played an important role in shaping the views of engineers, as well.

The Hungarian Hydrological Society has three thousand individual members as well as 150 institutional and company members that are acting on those professional fields that our Society covers.

The key to the effective functioning of the Hungarian Hydrological Society is that its individual members with different age, professional qualification and orientation can find events which are of interest to them, gather and exchange of information they are interested in.

It is also important that the institutional and company members of the Society also have access to professional information, and their representatives could participate in substantial society events.

The Society aims to provide its members with balanced, varied and colourful organization life in the future and with its specific means the Society intends to strengthen the cohesion of professionals in the water management sector. Our committed ambition is to strengthen the fact that it is worth to be a member of the Society and even it means rank. To this end, we are constantly looking on those operating methods, events and relation forms that are conform to the information revolution mechanism in the changing world. We wish to base the rank and attractiveness of the membership of our Society primarily on the social capital and knowledge base that can be increased with membership.

Our independent journal, the Hungarian Journal of Hydrology is published continuously since 1921, thus the Reader now holds the 3rd issue of the 96th Volume in hand.

On our website is open for all those who are interested in reading the Hungarian Journal of Hydrology. Through the Society's website all digitized issues can be accessed, thus many thousands of pages can be searched in facsimile format. With the online search system the entire text file of the papers in the system can be searched, thus this is a huge knowledge base that can actively and continuously be utilized in research and engineering practice.

The Hungarian Hydrological Society's *vision* is to uniformly represent the community of the experts working in the fields of national water management with adjusting the activities of the Society to the rapidly changing environment, still respecting the traditions as well as focusing on the development needs. Preservation of the traditions and flexible adaptation to the changing environment are in the centre of the Society's activities. Entering into the second century of the operation of the Hungarian Hydrological Society the keywords of our activities still remain: *tradition and progress. The Hungarian Journal of Hydrology intends to serve these principles.*

*Dr. Lajos Szlávik*
*President of the Hungarian Hydrological Society*

# Water connects

This is a special issue of the *Hidrológiai Közlöny*, the Hungarian Journal of Hydrology in English, devoted to the topics of the *Budapest Water Summit 2016* (BWS 2016) held in November 28-30, 2016, in Budapest (https://www.budapestwatersummit.hu/). It contains contributions to the Summit by the Hungarian water community from their vantage points.

The *Hidrológiai Közlöny* with its 96 volumes is one of the oldest technical journals in Europe devoted to water issues. Over the past ten decades it published studies ranging from water science and technology to water policy and practical problem solving. In this special number we attempt to present the history, present status and planned future directions of the Hungarian water science community in the context of the Sustainable Development Goal (SDG), more precisely SDG-6, and the goal that is devoted to water issues.

Fresh water is finite and universally sustains life as well as all aspects of human society. Its distribution, however, varies a great deal both in space and time, ignoring political boundaries and giving, therefore, rise to possible competition between uses and users. Increasingly felt global change phenomena, ranging from the impacts of population change, including migration, to those of climate variability, exacerbate the stress on world's water resources. Increased industrialization, urbanization and agricultural needs, a growing world population and the need to adapt to climatic changes place high demands on the planet's water resources — and therefore on our vital capacity to manage, govern and share water wisely at all levels.

Water connects almost all of our systems as well as people and cultures but it also is connected to some of the major issues of our times. What is it, for instance, that connects the various Sustainable Development Goals from poverty reduction to improved public health? What is it that manifests climate variability in a most impacting manner from sea level rise through changing precipitation fields to increased flood and drought frequencies? The answer, of course, is water. For it is water that helps us to find adaptation strategies to cope with the vagaries of climate change induced hydrological extremes. It is also water, or rather the lack of it along with poor sanitation that is responsible for putting millions at any moment in the world into hospital wards. Is it really water and is it not rather us that are responsible for this deplorable situation? I am afraid the answer is affirmative: Yes, we are all responsible. At the same time we all have a shared responsibility to change this unacceptable situation. We have the knowledge to do that, we have the technology to fix the technical issues but we still do not have enough will to put water to the highest political priority locally, regionally and globally. No doubt, great progress has been achieved since 1997, the *annus mirabilis* of breaking through the international political "water wall", however, it is still not enough. In forty years nine billion human beings will populate the planet Earth. Food production, therefore, needs to be doubled in less than three decades. That cannot be achieved without improving irrigation efficiency and without new systems. We indeed have enormous challenges that require comprehensive solutions more than ever before.

With the current world population living in urban areas within thirty five years is a rather horrifying thought. However, that is it what is expected to happen in 2050 with the nine billion people around. A totally new world is gradually emerging in front of our eyes with totally new issues and with never experienced changes in urban social fabric. The interconnectedness of political, social, security, public health, environmental, transport, energy, food and economic systems in this new urban context, interwoven with water all over, poses enormous challenges. The key here is water as it cuts through and connects all urban systems. Unless the water and sanitation situation is fixed, and fixed well, there is no way to achieve urban system sustainability. Things will likely get worse with the added uncertainties that are to come from increasing climate variability. Natural disasters such as pluvial or fluvial flooding, particularly flash floods in hilly areas coupled with landslides, will likely be on the rise. For sure, vulnerability will increase as more and more people will migrate to inappropriate peri-urban areas.

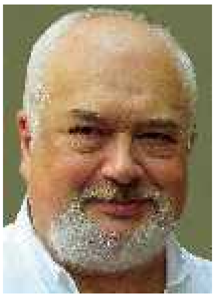
Some say we can live without oil and gas for ten days. Some say we can live for ten days without Internet. Some even add that, although difficult, we can live without love for ten days. But nobody says we can live without water for ten days. The message is so simple, yet so powerful! How to get this simple message through then to all who are concerned, particularly to the political community, in order to trigger effective actions at all levels?

In adopting the SDGs and the *Paris Climate Agreement* last year the world leaders are hopefully *en route* to recognize that water is *the* key to a sustainable world. It is an essential commodity to eradicate poverty and to provide access to enough water of good quality to satisfy vital human (for food, health and energy security), but equally importantly for ecosystems needs. The arid, humid and temperate landscapes do draw and sculpt our systems and living environment, and underpin our cultural diversity so vital for our survival.

We hope that the papers presented in this special issue of the *Hidrológiai Közlöny* will provide a quick overview on Hungary's approach to sustainable water management.

*Dr. András Szöllősi-Nagy*
*Chairman of the Editorial Board*

# Foreword



The *Hidrológiai Közlöny,* the Hungarian Journal of Hydrology, which is the professional periodical of the *Hungarian Hydrological Society* decided to prepare a special issue on the occasion of the 2nd Budapest Water Summit (BWS2) to be held in Budapest on 28-30 November 2016.

During its three day programme the BWS2 is going to discuss six main challenging topics about water resources and their management in global context, namely: i) How to provide safe and affordable drinking water?; ii) How to improve sanitation and hygiene?; iii) How to achieve increased water-use efficiency?; iv) How to do integrated water resources management?; v) How to improve water quality?; vi) How to manage water-related ecosystems better?

Some months ago the Editorial Board of the Hungarian Journal of Hydrology decided to publish a special issue prior to the BWS2 with the intention to give overviews of the water resources management in Hungary in connection with the topics that BWS2 is going to discuss. The Editorial Board invited specialists from members of the Hungarian Hydrological Society who have long term professional experiences on the topics of BWS2 to prepare focus papers.

In the 96 year long history of the Hungarian Journal of Hydrology papers in all previous issues were published in exclusively in Hungarian and only abstracts were provided in other language(s). This is the first time when the entire issue is in English.

The authors were requested to write their topic specific paper to present in concise way a) the historical background of the professional field; b) what development happened in recent decades in that field; c) what is the current situation / status; and d) provide an outlook for the next few decades about the expected /feasible development trends.

Six papers were prepared introducing and discussing i) Good Practices for Integrated Water Resources Management in EU and in Hungary; ii) Water supply in Hungary; iii) Sanitation in Hungary; iv) The power of irrigation; v) Water quality protection in Hungary - policy and status and vi) Water bodies in Hungary - an overview of their management and present state.

In the regular issues of the Hungarian Journal of Hydrology, besides professional papers additional columns are included, such as the *Köszöntő (Salutation)* column where members of the Hungarian Hydrological Society with outstanding career are greeted at their high age anniversary or the *Életút interjú* (*Biographical interview)* column where the presidents or elected leaders of the Society as well as highly recognised professionals working in the water management sector or water sciences are interviewed or the *Történelmi pillanatkép (Historical snapshot)* column, which gives brief information about interesting historical events, decisions, personalities, facts, etc.

In this special issue we provide – besides the issue specific papers - a brief snapshot also about the fact that scientifically based research about the water resources and ecological status of the Danube River and the watershed has been started more than 300 years ago and as one the main outcomes of that work was published in 1726.

Besides the six topics discussed in this issue the Hungarian Journal of Hydrology plans to present, in the next year volume, review papers on other significant water management issues, such as – among others - flood protection in Hungary in the integrated water resources management; Experiences in connection with the design end control works of reservoirs built in the Tisza Valley for flood level control; Surface water detention in the Danube –Tisza sand plateau region of Hungary; Wastewater irrigation - a stepchild of our water management and how medicinal and bathing water resources are used and managed.

Last but not least, I'd like to thank all authors of the papers for their work and the considerable amount of their private time they spent on finalising this issue. Without their voluntary contribution this issue would not have been published.

I also greatly appreciate and thank for the support of Professor Emerita Mária Dulovics, Dr. Zsuzsanna Horváth, Dr. Veronika Major, Professor Emeritus István Ijjas, Hon. Professor Endre Juhász, Assoc. Professor Ferenc Szilágyi, Dr. József Gayer, Dr. Károly Konecsny and Mr Géza Csörnyei who reviewed the papers and advised the authors how to improve them.

*Dr. János Fehér*
*Chief Editor of the Hungarian Journal of Hydrology*

# Historical snapshot

**The 290 years ago released "Danubius Pannonici Mysicus ..." six-volume, historically important natural science monograph, which gives the description of the Hungarian and Serbian Danube section, is a significant example of a 18th century European scientific cooperation. The background and appearance circumstances of the monograph are reviewed by László Fejér, section editor of the Hungarian Journal of Hydrology.**

## Danubius Pannonico-Mysicus … a European scientific cooperation in the 18th century

In 1726, in Amsterdam a beautiful publication was released namely Count Ferdinando Marsigli's six-volume scientific work on "Danubius Pannonici Mysicus ..." from one of the print works.. According to the title of the publication, the description of the Hungarian and Serbia section of the Danube was an unique undertaking, as a scientific summary was published from such an area that was liberated from the Ottoman rule only few decades earlier. It was no coincidence of the proud statement of the author Marsigli: "I was the first person, who brought into prominence …from its barbaric unknown character ... this remote hidden world..." *(Deák 2004)*. A question may immediately arise, how a Northern-Italian Count get to the historical Hungary, and why his epochal work was published in the Netherlands?

Marsigli, who inured in the University of Bologna, became officer of the Habsburg armada at young age and because of the unpredictability of wars, he became prisoner of wars and miserable slave of the Turkish army. He was eventually freed by ransom, and – in possession of rich Balkan experiences – he defected again to the imperial army. *"I'm a soldier, but in my life I always found the esteem of books and science necessary."* His quick military success, thanks to his monitoring, mapping and analytical knowledge, assured him a rapid military advancement. He has used his position in favour of scientific research of those territories he took also possession of. Wherever he turned up, he made notes, drawings and sketched-maps, and he slowly formulated the idea of preparing a monograph on the Danube. All these coincided with the aspiration of the emperor and his surroundings to get better acquainted with and utilize the economic circumstances and resources of the new domain for further wars. Leopold I provided financial support to the preparation of the upcoming scientific works. Marsigli, although in terms of his interest, he was a true Renaissance man, but he was not familiar with the deeper knowledge of individual disciplines. However, he was very good at finding those scientists who helped him in his work with their experiences, working methodologies or carrying out certain measurements and research. He gradually started to operate an international team through correspondence or with his representatives. His most reliable cartographer was Johann Christoph Müller, but he often turned for advice to the outstanding geographer Domenico Cassini. Those who worked for him were Georg Eimmart of Nuremberg and the Hungarian Dávid Rozsnyai, or Paulus Ritter from Zagreb, but he was in close contact with the Newton led the Royal Society, as well. When he measured the flow velocity of the Danube at individual locations, he asked for advice from the famous Domenico Guglielmini. It should be noted that Marsigli carried out these measurements not so much for a definite purpose, but rather for his scientific interest. If the 18th century is considered as the century of adventurers, than Marsigli belonged, in good sense, to the "adventurers" of the science.

And why the work was published in Amsterdam a quarter of a century later than the observations and the research were made? Well, the reason was that Marsigli who was not only disgraced, but stripped of his military rank and any of his assets, because of surrendering the besieged Breisach fortress in 1704, in the War of Succession, which took place between Leopold I and the King of France, Louis XIV. Under these circumstances, the Emperor withdrew the support, and Marsigli had to stealthily rescue his materials and illustrations on copperplates to his home town Bologna. Here, the finalization of manuscripts began as well as preparation of other maps, and drawings, which work progressed very slowly due to the scarcity of finances. Finally, the finding of right print work, the back and forth secure transportation of the high-value copper plates, and above all, to ensure the authors' rights meant serious, but rather most time-consuming negotiations...

Topics of the six large-sized volumes are as follows: I. The peoples of the Danube, as well as its geographical, hydrological conditions, II. Roman relics, III. Minerals, IV. Fish, V. Birds live along the Danube waters and their nests, VI. Various observations.

The book "... Danubius” is a real rarity. Its complete series are available only in 4-5 libraries in Hungary. Therefore it caused a sensation in professional circles when in 1983 the Borda Antiques offered to purchase the volumes for the Hungarian Museum of Water. After obtaining licenses from various authorities, the business was signed. The task of studying and translation of the monograph written in 18th century Latin language was the responsibility of Museum scientist Dr. András Deák, who over many years did research in Bologna and Vienna, and became one of today’s best known Marsigli researcher. He translated the first volume describing the hydrographic conditions, which volume was published by the Water Public Collections (VMLK) in 2004. The interesting fact of this reprint publication is that the translation is available not only in Hungarian, but also in English, together with a bilingual extensive paper of the translator.

Literature:
*Deák A. A. (2004)*. A Duna fölfedezése (The discovery of the Danube) – Luigi Ferdinando Marsigli Danubius Pannonico-Mysicus Tomus I. A Duna magyarországi és szerbiai szakasza (The Hungaraian and Serban section of the Danube), Vízügyi Múzeum, Levéltár és Könyvgyűjtemény (Water Muzeum, Archive and Book Collection)

# Good Practices for Integrated Water Resources Management in EU and in Hungary

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**Abstract**
The main objective of the paper is to provide an overview on the good practices of integrated water resources management (IWRM) in Hungary. The total area of Hungary belongs to the Danube Basin and the country is member of the EU. Therefore, the good practices of IWRM are discussed together: in the levels of EU, the Danube Basin and Hungary. The paper underlines the important need for good practices of integration, provides an overview of the history, the present status and future challenges of IWRM in Hungary. The paper discusses the good practices for integration of water and environmental policies in EU level, in large river basins and macroeconomic-regions, and for integration of water protection policy and inland navigation and hydropower development policy. The Integrated Tisza River Basin Management Plan, the implementation of RBM planning under the EU WFD in Hungary, and finally, the fully IWRM versus WFD issue are also discussed.

**Key words**
Integrated water resources management, river basin management, Water Framework Directive, good practices for IWRM, Danube Basin

## INTRODUCTION

The paper provides an overview of the history, the present status, and future challenges of integrated water resources management (IWRM) and good practices of IWRM in Hungary, being a member of the EU, and the total area of which belongs to the Danube Basin. Major challenges of integrated water resources management to be addressed are similar at various levels, such as the EU, the Danube Basin and Hungary (*GWP 2015*). These are why, these issues are discussed together at different levels.

IWRM has been discussed as principle and practice by several recent international conferences, world forums and international summits, and manuals (*GWP 2003, 2012, Shah 2016, UN-Water 2008, UN 2012*). It is also the core principle of River Basin Management Planning (RBMP), according to the EU Water Framework Directive (WFD).

### Need for good practices of integration

The WFD sets clear guidelines for production, review and updating of the river basin management plans for the achievement of the environmental objectives, but it lacks providing guidelines for the planning of measures for the achievement of social and economic objectives. For an effective RBMP it is necessary to develop management and planning practices, and practices of integration, linking social and economic development with the protection of natural ecosystems. National and international guidelines should be developed to achieve the environmental, social and economic objectives (*GWP 2015*).

EU Member States shall ensure in the RBMPs the establishment of the programme of measures, and to achieve the environmental objectives established under Article 4 of WFD. An efficient inter-sector collaboration (the good practices of integration), particularly between agriculture, rural development, water industry, energy production, transportation, tourism, climate adaptation, and nature conservation should be developed, to support the identification of the most cost-effective combinations of measures to achieve the environmental, social and economic objectives.

## HISTORY OF INTEGRATED WATER RESOURCES MANAGEMENT IN HUNGARY

Integrated water resources management is not an entirely new concept or activity in Hungary. One of the first publications related to the IWRM concept (*GWP 2015*) was a manual “Multiple-Purpose River Basin Development”, published in 1955 by the UN and three years later, another report on “Integrated River Basin Development” (1958) was published also by the UN. In the 1970s, there was a series of UN-sponsored studies and events with active participation of Hungary.

### UN Seminar on integrated river basin development in Budapest, Hungary in 1975

An Interregional Seminar on River Basin and Inter-Basin Development, organized by the United Nations and sponsored by the United Nations Development Programme was held in Budapest, Hungary, from 16-26 September 1975 (*UNDP–NWA Hungary 1976*). The Seminar was attended by 72 participants from 33 countries in Africa, the Americas, Asia, Europe and the Middle East, and by representatives of four international organizations. The seminar reviewed and discussed selected policy issues of river basin development and management with special emphasis on the interrelations between river basin development and over-all socio-economic growths, the role of ex-post evaluations in decision making and planning, and issues relating to cooperative management and development of river basins shared by two or more countries. The introductory overview by Dégen discussed the major ideas of the integrated approach in water management and perspectives of the integrated development of river basins.

### History of IWRM planning in Hungary

Hungary has a long tradition in water management planning (*Ijjas and Tóth 2000, UNDP-NWA Hungary 1976*). The major regional/national (integrated) water management plans in Hungary are:

*The General Tisza Regulation Plan, 1845/46*

The first example of comprehensive, regional water management planning in Hungary is the general regulation plan of the River Tisza, prepared by Pál Vásárhelyi in 1845/46. The plan has served for long years as the basis of water management developments in the Tisza Valley.

*Irrigation Master Plan for the Trans-Tisza Region, 1937*

Following several long-term water management concepts developed in the first half of the 20th century, the water policy formulated in the 1930´s had far reaching effects, as a part of which a master plan was prepared in 1937 for irrigation in the Trans-Tisza Region (the region to the East of the River Tisza). Implementation of the plan extended to the second half of the century.

*National Master Plan of Water Management, 1954*

The first comprehensive national Water Management Master Plan was completed in 1954 and identified primarily the water use objectives for a time horizon of 15 years.

*National Master Plan of Water Management, 1965*

Work on the second Water Management Master Plan was completed in 1965. Starting from the situation in 1960, development projects considered technically desirable were outlined therein for the period from 1960 to 1981 and beyond, going into slightly warranted details and in some branches, like irrigation, industrial water supply, water transport, hydropower development, with over-ambitious prognoses, which did not materialize to these days. In some branches, on the other hand, (e.g. domestic water supply) the actual progress has surpassed the prognosticated one.

*International Master Plan of Water Resources Management of the Tisza River Basin, 1977*

The Tisza River Basin is shared by five countries, which strived for flexible and continuous cooperation. Co-operation established under the Council of Mutual Economic Assistance (CMEA) was extended to the preparation of the Integrated Water Management Master Plan of the Tisza Basin (including improvement of flood control, water pollution control, ground water use and protection, irrigation, etc.). It was an international, integrated river basin management plan (*Dégen 1974, OVF 1977*).

*National Master Plan of Water Management, 1984*

The third National Water Management Master Plan was published in 1984. This reflected a philosophy departing from that underlying the former ones. Instead of controlling long-term water management development, it was intended to form part of the planning process in which an updated situation assessment is presented, opportunities are identified and decision options are offered as the groundwork of further planning.

*Integrated river basin management planning 1993-1998*

In autumn 1993 a committee has been set up by the National Water Authority (OVF) with the responsibility to draft general guidelines on RBMP. According to the Hungarian Guidelines drafted in 1994 (*National Water Authority 1994*), RBM plans represented a vision of water management within river basins, set water management and environmental objectives and guides all uses, and, indirectly, the whole water environment to comply with these objectives. The existing status of the water environment was compared with the objectives and from this comparison, management options were developed. Using the guidelines, 7 river basin management plans were completed in the period 1996-2000.

The seven river basins and the periods of planning were:

- Általér River Basin, 1998
- Felső Bácska River Basin, 1997
- Hortobágy-Berettyó River Basin, 1996-1998
- Hungarian Part of the Hernád River Basin, 1997-1998
- Hungarian Part of the Maros River Basin, 1997-1998
- Lónyai-főcsatorna River Basin, 1998
- Sajó-Bodva River Basin, 1998

### River Basin Management under the EU Water Framework Directive as part of IWRM

The EU Water Framework Directive (WFD, 2000/60/EC) came into force in December 2000. The purpose of the Directive is to establish a framework for the protection and enhancement of the good status of inland surface waters, transitional waters, coastal waters and groundwater, and to ensure a sustainable use of water resources. EU Member States (EU MS) should aim to achieve 'good status' in all bodies of surface water and groundwater by 2015, respectively by 2027 at the latest (*EC 2000*).

In Hungary, the 12 regional water authorities have been organized in the 1950s on the river basin principle. Later, for planning purposes under the implementation of WFD, 33 river sub-catchment units were identified in 1996. Half of these units are situated totally within Hungary, the other half are of transboundary character.

The EU Water Framework Directive (WFD) plays a leading role and is the key tool for water policy integration in EU, specifying water protection targets in balance with economic interests. The WFD is one of the core policy elements for integrated water management, but many other environmental and other directives, economic sector policies and conventions need to be considered for comprehensive policy integration related to infrastructure development.

## GOOD PRACTICES FOR INTEGRATION OF WATER AND ENVIRONMENTAL POLICIES IN THE EU

### Coordination and Assessment of River Basin Management Planning in EU level

Implementation of the WFD has been supported at EU level since 2001 by an unprecedented informal co-operation under the Common Implementation Strategy (CIS), led by Water Directors of Member States and the

EU Commission with participation from all relevant stakeholders. The CIS has successfully delivered more than 30 guidance documents and policy papers and has been a valuable platform for exchange of experiences and best practices on implementation among Member States.

The European Commission has to assess the progress in the implementation of the WFD in certain intervals and to inform the European Parliament, the Council and the public about the results of the assessments. Three implementation reports have been produced in 2007, 2009 and 2012 (*EC 2013*).

### Integration of water and environmental policy in case of new infrastructure projects

A considerable number of new infrastructure projects are at different stages of planning and preparation in EU Member States and in Hungary. These projects provoke pressures and can deteriorate water status, but are at the same time beneficial in terms of socio-economic aspects and climate change mitigation. This can be the case for multifunctional use of infrastructure projects serving different purposes, including the mitigation of floods and droughts and ensuring water resources for different water users by the seasonal and/or multiannual regulation of water flows.

The application of WFD Article 4.7 is key for new infrastructure development and for integration of environment and economy. The related requirements for exemptions, according to the Article 4.7, WFD include amongst others that:

- the benefits of the new infrastructure are of overriding public interests outweighing the benefits of achieving the WFD environmental objectives,
- there are no significantly better environmental options which are technically feasible,
- all practicable mitigation measures are taken to minimize negative effects on the aquatic ecology,
- the projects are reported in the River Basin Management Plans.

### WFD CIRCABC - The Information Exchange Platform

One of the key activities under the joint implementation of the WFD is the improvement of the information exchange between the EU Member States, the EU institutions, the various stakeholders and the interested public. In order to promote information exchange and to facilitate the work of the experts (the process of social learning), the European Commission set up an internet-based platform called "CIRCA" which has recently migrated to a new platform called "CIRCABC" (**C**ommunication and **I**nformation **R**esource **C**entre for **A**dministrations, **B**usinesses and **C**itizens). It is a web-based service provided by the European Commission. It is used to create collaborative workspaces, where communities of users can work together and share information and resources.

### Legal tools of EU for integration of environment and economy

Over the last 30 years, EU legislation has developed much in terms of environmental protection and improvement. However, as more Directives have been adopted, the regulatory requirements have become more complex, and the implementation has become more complicated. Therefore, a coordinated and harmonised implementation is needed. One of the major objectives of the WFD, the EIA and SEA Directives, the Public Participation Directive and the Birds and Habitats Directives (BH-D) is to integrate the environment into decision-making process.

## IWRM UNDER THE EU WFD IN LARGE RIVER BASINS

### The Danube River Basin

The Danube River Basin (DRB) is the "most international" river basin in the world, located on the territories – fully or partially - of 19 countries. The Danube River Basin has been the subject of many environmental investigations and studies funded by the countries sharing the Basin, a wide range of organizations and the EU:

- Regional co-operation of the Danube countries in the frame of the International Hydrological Program (IHP) of UNESCO (1974-)
- The Danube...for whom and for what, Equipe Cousteau (1992)
- Danube Integrated Environmental Study, Environmental Programme for the Danube River Basin, EC PHARE-Programme (1993-1994)
- Strategic Action Plan (SAP), Environmental Program for the Danube River Basin (1994)
- SAP Implementation Plan (1995)
- Danube Nutrient Reduction Program (1997 –1999)
- ICPDR Joint Action Plan 2000- 2005
- EC supported DABLAS program (specific reports in 2002 and 2004)
- EU WFD Danube River Basin Analysis (2005)
- UNDP/GEF Danube Regional Project (2001 – 2006)
- UNDP-GEF-ICPDR Danube River Basin Updated Transboundary Diagnostic Analysis Based on EU Water Framework Directive - Analysis Report (2006)
- First Danube River Basin Management Plan (2009)
- Second Danube River Basin Management Plan (2015)
- First Danube Flood Risk Management Plan (2015)

Those 14 countries with territories greater than 2,000 km² in the DRB, cooperate in the framework of the International Commission for the Protection of the Danube River (ICPDR). The Danube River Protection Convention (DRPC), signed in 1994, provides the legal framework for cooperation on water issues within the Danube basin.

Transboundary cooperation had a long history in the Danube Basin. Today, scholars of international law often identify the Danube Basin as the region where international organizations first evolved (*ICPDR 2014*). The International Commission for the Protection of the Danube River (ICPDR) is now the largest international body of river basin management experts in Europe, with a mission to promote and coordinate sustainable water management in the Danube Basin. The work of the Danube countries under the ICPDR provides a model of transboundary cooperation to guide actions for sustainable development in the river basins all around the world (*ICPDR 2016*).

When the ICPDR started its work in 1998, Germany and Austria were the only two contracting parties belonging to the European Union. Today, nine of the fourteen countries in the Danube region are EU member states.

The Danube River Protection Convention is referred as an example of good practice in a wide range of themes of IWRM. Efficiently coordinated by the ICPDR, the Danube Basin has a transboundary river basin management plan (*ICPDR 2009c*, *2015a*), a transboundary flood risk management plan (*ICPDR 2009b, 2015b*), the first-ever transboundary climate change adaptation strategy (*ICPDR 2013c*) and shares its experiences as part of a global network of basins working on climate change adaptation. ICPDR is a world leader in work on the nexus between water and related sectors, having developed guidelines on sustainable waterway (*ICPDR 2010*, *ICPDR-DC-ISRBC 2007*, *Ijjas 2014b*) and hydropower planning (*ICPDR 2013a*, *2013b 2012*) together with the interest groups. Active involvement of the public was one of the key principles of the Danube River Protection Convention (*ICPDR 2014*). To date, 22 organisations hold observer status in ICPDR, representing the full spectrum of interests.

### Good practices for river basin management and coordination in large river basins

The River Basin Management Planning and coordination needs a specific understanding in large river basins (*ICPDR 2009c and 2015a*, *Ijjas 2004 and 2006*). The three main levels of planning and coordination in case of the Danube Basin:

- Danube river basin level (issues affecting the whole DRBD)
- Bilateral/multilateral level (issues with bilateral, multilateral transboundary effects)
- National level (all other issues regarding implementation)

Amount of Danube level planning and coordination should be limited to the absolutely necessary. The subdivision of the Danube River Basin into practical management sub-units is also an important issue. Transboundary issues NOT covered by the WFD are the problems affecting the achievement of economic and social objectives (e.g. navigation, recreation, CAP) and also the programs of measures to achieve the economic and social objectives.

### Integration for achievement of good status of waters - Danube River Basin Management Plan

The Danube countries have developed the DRBM Plan entailing measures of basin-wide importance as well as setting the framework for more detailed plans at the sub-basin and/or national level (*ICPDR 2009c, 2015a*). Not all countries of the Danube Basin are EU Member States, but all the countries have agreed to adopt and implement the WFD.

The DRBM Plan identified four major significant transboundary issues that are a priority for the Danube Basin and the impact of the Danube River on the Black Sea (*ICPDR 2009c, 2015a*):

1) Nutrient Pollution – potentially leading to over enrichment by nutrients and eutrophic conditions.
2) Organic Pollution – potentially leading to low dissolved oxygen levels in the receiving water.
3) Hazardous substances – potentially leading to environmentally toxic conditions.
4) Hydromorphological alterations – that have led to a loss of wetlands, negative impacts on natural aquatic conditions and present migration barriers for fish.

### Good practices for integration of development policies in macro-regional level

The EU Strategy for the Baltic Sea Region (EUSBSR) was adopted in 2009, the EU Strategy for the Danube Region (EU SDR) in 2011, and the European Council invited the European Commission to present an EU Strategy for the Adriatic and Ionian Region by end 2014. The aim of a macro-regional strategy is to mobilize new projects and initiatives, creating a sense of common responsibility.

The EU Strategy for the Danube Region (EUSDR) was jointly developed by the European Commission, together with the Danube Region countries and stakeholders, in order to address common challenges together. The Danube Region Strategy (*EC 2010*, *Ijjas 2011*) addresses a wide range of economic, social and environmental development issues; these are divided among 4 pillars and 11 priority areas. Each Priority Area is jointly coordinated by two participating countries. The objective of the Priority Area 4 is “to restore and maintain the quality of waters” (implementation of WFD and the measures of river basin management plans). The area is coordinated by Hungary and Slovakia. Priority Area 5 "To manage environmental risks" is coordinated by Hungary and Romania, with the involvement of a wide network of key players and stakeholders from the 14 countries of the Danube Region.

## INTEGRATION OF WATER PROTECTION POLICY AND SECTOR POLICIES

### Integration of water protection policy and inland navigation policy

ICPDR (actually the ministers responsible for water and environment in the countries sharing the Danube Basin) considered the integration of environment and agriculture, navigation and hydropower as the most important integration issues in the Danube Basin.

In 2007, the International Commission for the Protection of the Danube River (ICPDR, Vienna), together with the Danube Commission (DC, Budapest) and the International Sava River Basin Commission (ISRBC, Zagreb), initiated an international dialogue to create a basis for improving navigation while at the same time protecting and improving the natural landscape and water quality of the Danube. An intensive one-year discussion process resulted in an agreement, called the Joint Statement on

Guiding Principles for the Development of Inland Navigation and Environmental Protection in the Danube River Basin (*ICPDR-DC-ISRBS 2007*). The Joint Statement provides guiding principles and criteria for the planning and implementation of waterway projects that bring together the conflicting interests of navigation and the environment.

The Joint Statement is internationally recognized as a milestone for the development of the inland navigation in the Danube region and an example of similar areas in Europe. For the first time, a common discussion and planning platform was created to address the potential conflict between waterway development and environment protection. The Joint Statement assists in the prevention of conflicts and the creation of integrated solutions. Its application provides planning security for new infrastructure projects.

To facilitate manual on sustainable waterway planning to be applied as a reference and practical tool in and ensure the application of the Joint Statement, there was an obvious need to prepare the good practice the Danube and other European river basins by inland waterway planning authorities and interested stakeholders (*ICPDR 2010, EC 2012a*).

### Integration of Water Protection and Hydropower Development policy - Good practices for sustainable hydropower planning and operation

The "Guiding Principles on Sustainable Hydropower Development in the Danube Basin" (*ICPDR 2012, 2013a, 2013b*) have been elaborated in the frame of a broad participative process, with the involvement of representatives from administrations (energy and environment), the hydropower sector, NGOs and the scientific community.

A strategic planning approach was recommended by the Guiding Principles for the development of new hydropower stations (*Box 1.*). This approach should be based on a two-level assessment, the national/regional assessment followed by the project specific assessment. This approach is in line with the prevention and precautionary principle as well as the polluter pays principle of EU water policy and it could be efficient tool also for planning of reservoirs and other hydraulic structures.

**Box 1. Strategic planning approach for new hydropower development**

1) The strategic planning approach (linked to the Renewable Energy Action Plan and the River Basin Management Plan) is based on a two-level assessment: the national/regional assessment followed by the project specific assessment.
2) In a first step those river stretches are identified where hydropower development is forbidden by national or regional legislation/agreements. In a second step all other stretches will be assessed using the assessment matrix and classification scheme.
3) The national/regional assessment is an instrument for administrations in the process of directing new hydropower stations to those areas where minimum impacts on the environment are expected. This can be achieved by an integration of hydropower production and ecosystem demands as well as by supporting decision making through clear and transparent criteria, including aspects of energy management as well as environment and landscape aspects.
4) The national/regional assessment is beneficial and provides gains for both, the environment and water sector but also for the hydropower sector by increasing predictability of the decision-making process and making transparent where licences for new projects are likely to be issued.
5) While the assessment on national/regional level is more of general nature, classifying the appropriateness of river stretches for potential hydropower use, the project specific assessment provides a more detailed and in-depth assessment of the benefits and impacts of a concrete project in order to assess whether a project is appropriately tailored to a specific location. The assessment on the project level is carried out in response to an application for issuing the licence for a new hydropower plant and therefore especially depends on the specific project design.

Source: *ICPDR 2012, 2013a, 2013b*

### Integrated Tisza River Basin Management Plan

The Tisza River is the longest tributary of the Danube. Its basin is the largest sub-basin of the Danube Basin – 157.186 km2 - and home to 14 million people throughout five countries – from upstream to downstream: Ukraine, Romania, Slovakia, Hungary and Serbia.

The Tisza countries agreed to prepare an integrated sub-basin management plan (the Integrated Tisza River Basin Management Plan – ITRBM Plan), which integrates issues of water quality and water quantity, land and water management, floods and drought (*ICPDR 2009a, ICPDR –UNDP GEF 2011*). The draft ITRBM Plan was developed in 2010, submitted to public participation process and the final plan was introduced to the ICPDR Tisza Countries Heads of Delegation in December 2010. The ITRBM Plan accounts for both water quality and water quantity issues, to identify measures which will have positive impacts both on water quality and quantity and on aquatic ecosystems in the Tisza River Basin. The specifics of ITRBM Plan compared to river basin management plans under the WFD that ITRBM Plan introduces the methodology developed for integration of floods and excess water, droughts and water scarcity and climate change.

## IMPLEMENTATION OF RBM PLANNING ACCORDING TO THE EU WFD IN HUNGARY

Hungary has particularly rich and long-lasting experience in water management that always incorporated the most important international trends, scientific and technical outcomes. The EU membership for Hungary however represented a basically new quality in RBM planning and in international relations including water management issues. The EU Member States introduced common principles and regulations to co-ordinate their efforts to improve the protection of waters, to promote the sustainable water use, to contribute to the control of trans-boundary water problems and to protect aquatic ecosystems.

RBMPs must be reviewed and updated every 6 years. The review and the update to the RBMPs appropriate public consultation and engagement methods are used.

The first Hungarian River Basin Management Plan has been published in 2010 (*VKKI 2010*), and the second RBMP has been approved in 2016 (*OVF 2016a*). They have been prepared in line with EU and Hungarian guidance, fulfil the requirements of the WFD and contribute to the objectives of other EU directives.

Since Hungary is situated within the heart of the Danube Basin, the country is involved only in one river basin district. Danube-basin-wide issues are coordinated by the International Commission for the Protection of the Danube River (ICPDR). It has been agreed among the Danube-countries that the river basin management plan would be structured so that the plan can be studied on the basin, national and sub-unit level. Therefore, part A of the plan deals with issues of basin wide importance (so called roof level) and is coordinated by ICPDR, while part B is the national plans of the countries of the basin with the responsibility of the competent authorities. More detailed plans (part C) can be integral part of national plans.

The Hungarian national RBM plans are prepared at three areal levels: - country (93,030 km2) - 4 sub-basins (River Danube– 34.730 km2, River Tisza – 46.380 km2, River Dráva – 6.145 km2 and Lake Balaton – 5.775 km2) - and 42 planning sub-units. The smallest planning units are the water bodies. In the second Hungarian RBM Plan 1078 surface water bodies (889 river and 189 lake water bodies) and 185 groundwater bodies have been identified (*OVF 2016a*). The information increases in detail from Part A to Part B and C, and from national to sub-basin, sub-units and planning sub-units. The national RBM Plan represents Part B and assesses water management issues at a more detailed scale than the Danube RBM Plan.

The RBMPs contains all available and relevant information on the water bodies, the results of status assessment, the significant water management issues and their causes, the environmental objectives and the programme of measures (PoM) with the required financial support to reach them. The time horizon of the PoM extends till 2027 (the end of the third planning cycle according to WFD) and has been based on a multi-level public participation process. The basin-wide measures of the sub basin and sub-unit level PoMs are firmly based on and were coordinated with the national programmes of measures and with Danube Basin-wide measures. Regarding the PoMs, special attention has been paid to the identified measures, their basin-wide importance, to the identification and implementation of priority measures and to measures that lack adequate funding.

Cooperation with neighbouring countries is a significant priority in Hungary. Existing agreements on transboundary waters is harmonized to certain extent with the relevant provisions of international agreements and EU regulations. Hungary actively participates in the collaboration under the various international treaties and in the international organizations, which deal with the problems of freshwater resources. The WFD is one of the most significant legislative instrument in the water field that was introduced on an international basis.

Hungary has a long tradition in flood management, however the first Flood Risk Management Plan based on the EU Flood Risk Management Directive, is a new milestone in flood-management in Hungary towards sustainable flood risk management (*OVF 2016b*). It addresses all aspects of flood risk management focusing on prevention, protection and preparedness, includes measures for achieving the established flood risk management objectives.

The fully integrated water management will be based in Hungary on the 'Jenő Kvassay Plan – National Water Strategy'. The draft Plan (*OVF 2016c*) is currently introduced and consulted.

## IWRM VERSUS RIVER BASIN MANAGEMENT UNDER THE EU WFD

The WFD is sometimes called the "IWRM of the North" and is considered as Europe's way of implementing IWRM. They are synonymous in many ways, but equally there are differences between the two. WFD is a core policy element for IWRM and, as such, it is a key tool for water policy integration, which specifies water protection targets in balance with economic interests, but WFD alone is not sufficiently balanced with socio-economic development goals. IWRM has a much broader focus on sustainable social and economic development and not just on the environment and River Basin Management under the WFD, however there are very good parts of the WFD (basin approach, public participation, precautionary principle, transparency) that fall within IWRM. The EU WFD stipulates the planning of action plans necessary for meeting the environmental objectives and do not deal with programmes related to social and economic objectives. WFD might be then considered as IWRM in the North European countries, mainly for countries where water is abundant and water infrastructure in place (*INBO 2006*).

The form of implementation of the WFD and IWRM is influenced by the highly diverse hydrological and economic conditions, geographical circumstances, socio-cultural factors, government structures, traditions and the national cultures of EU countries.

For an effective IRBM it is necessary to develop the management and planning practices and the practices of integration, and linking social and economic development with the protection of natural ecosystems (*EC 2012b*). National and international guidelines should be developed to achieve the environmental, social and economic objectives (*GWP 2015*).

EU Member States are expected to take an integrated approach, particularly bringing together the water interests of agriculture, rural development, municipalities, energy, transport, tourism, climate adaptation, and nature conservation, and to identify the most cost-effective combinations of measures to achieve environmental, social, and economic objectives. *Table 1* summarises the two approaches to IWRM – to meet both the WFD objectives of good environmental status and the broader social and economic objectives implicit in IWRM.

*Table 1. Approaches to integrated water resources management (Source: Ijjas 2014a)*

| Type of IWRM | Fully integrated water resources management<br>IWRM for WFD objectives | IWRM for national objectives |
|---|---|---|
| Types of objectives | Mandatory environmental objectives | Non-mandatory social and economic objectives |
| Objectives | Common European environmental objectives.<br>Good status of all surface and ground waters; good status of protected areas | European, national, regional, and local social and economic objectives:<br>sustainable water use/water services |
| Legal background | EU Water Policy;<br>EU WFD; related directives | National policies, strategies, action plans and laws.<br>EU policies, strategies, action plans; EU Flood Risk Management Directive;<br>international agreements |
| Types of planning | River Basin Management Plans under the EU WFD | National, regional, and local plans including coordination of sector plans (rural development, spatial planning, drought management plans, climate adaptation, and flood risk management plans) |
| Deadlines for achieving objectives | 2015, 2021, 2027; mandatory | No common deadlines; not mandatory |
| Planning guidance | EU CIS guidance documents – more than 30 guidance documents covering various aspect of WFD<br>International Commission for the Protection of the Danube River (ICPDR) guidance documents | National/international guidance documents, handbooks, manuals<br>GWP toolbox for guidance on IWRM<br>ICPDR manuals for sustainable navigation and sustainable hydropower production |
| Planning outputs | Programmes of measures to achieve environmental objectives | Programmes of measures to achieve the social and economic objectives |
| Monitoring objectives | Monitoring environmental indicators | Monitoring indicators for water use and water services |
| Target groups | Ecosystems (good status);<br>citizens (human security - good health) | Citizens/stakeholders;<br>interest groups |
| Public participation | Mandatory | Optional; mandatory for so called "interested parties" – direct water users |

## ADOPTING IWRM – WHERE ARE WE?

This paper reviewed progress across the EU and Hungary towards adopting IWRM and the good practices putting its principles into practice. As the EU Membership, over the past decade progress has been made in Hungary and in the EU towards improving water quality and meeting the WFD requirements. In the water sector, the environment and water quality requirements of the WFD dominated water resources planning and management.

The WFD sets clear guidelines in production, review and updating of the river basin management plans for the achievement of the environmental objectives, but it lacks guidelines for the planning of measures for the achievement of social and economic objectives. For an effective RBMP it is necessary to develop the management and planning practices and the practices of integration, linking social and economic development with the protection of natural ecosystems. National and international guidelines should be developed to achieve the environmental, social and economic objectives.

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# Water Supply in Hungary

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**Abstract**
Due to the favourable hydrogeological circumstances, Hungary has a solid access to renewable water resources, which could provide about 10 000-m$^3$/capita/year water availability for different usages. While the country's surface waters originate dominantly (96%) from upstream countries, and thus the country is susceptible to impacts coming through the border, the public water supply is based almost exclusively on subsurface water resources, which are much more secured internally.
This paper focuses on public water supply issues of Hungary. It discusses first, what water resources the country can use. In the second part of the paper, a concise overview is given about the history, current status and some future perspectives of the public water supply industry in Hungary.

**Keywords**
Public water supply, water balance, water abstraction, water consumption

## INTRODUCTION

This paper intends to give an overview about the public water supply situation in Hungary. The advent of the organised public water supply in the country – first mostly in larger cities - is dated back to the 17$^{th}$-18$^{th}$ century. Due to the favourable hydrogeological circumstances of Hungary water resources for public water supply were accessible almost everywhere in the country. First, the paper gives a short overview of surface and subsurface water resources in term of overall water balance of the country with some discussion on main water usages. This is followed with a view on what could be expected in middle term when climate change is taken into account.
In the second part of the paper we briefly introduce the historical development of public water supply, the current service level in terms of utility gap, organisational structures of service providers, tariffs, etc., and at the end we discuss the aspects of longer term sustainability of public water supply in the country.

## SURFACE WATER RESOURCES

Hungary is situated in the middle of the Danube River Basin, lying at the bottom of the Carpathian basin, which is constituted largely of lowland areas. The Danube, which on its 2850 km way from the Black Forest to the Black Sea, collects water from the territory of 19 countries, is the most international river in the world. Everything that happens upstream from Hungary is reflected in the Danube, be it its water quality, quantity, alluvium or wildlife.

Of the 7 countries Hungary borders with, 6 are upstream from us. With the exception of 3 smaller rivers, all our major watercourses come from beyond our borders and leave through three main rivers (Danube, Tisza and Dráva). Hungary's exposure is indicated by the fact that 96% of our surface water resources is of foreign origin.

Every year, an average of 109 km$^3$ of water reaches our country through watercourses, and the 600 mm annual precipitation falling on the territory of Hungary is 56 km$^3$. Of this, 48 km$^3$ of water evaporates, 3.3 km$^3$ infiltrates into the soil and feeds subsurface waters and 4,6 km$^3$ makes its way to watercourses. The rivers leaving the country carry an average of 116 km$^3$ of water annually.

The distribution of surface water resources in the territory of Hungary is uneven both in space and time. 70% of the overall runoff is concentrated in the watercourses in the Western part of the country, namely in the catchment areas of the Rivers Danube and Dráva, whereas the River Tisza, whose catchment area covers nearly half of the country, only gathers 30%. The temporal unevenness is even more apparent. In summer, at the time of the greatest water demand, the River Tisza and its tributaries carry only 28% (246 m$^3$/s) of their average water discharge of 854 m$^3$/s, whereas the Danube and the Dráva combined, characterized by much more balanced flow rates, carry an average of 1996 m$^3$/s, 70% of their average flow of 2835 m$^3$/s.

Precipitation is unevenly distributed: the East of the country generally receives less. What is more, in the south of the Great Plain, where the number of sunny hours is higher than the national average, the evaporation and precipitation ratio may be as high as 1.5. This increases the probability of droughts, which generally occur in Hungary every 3-5 years.

## SUBSURFACE WATER RESOURCES

With a few exceptions, the spatial distribution of groundwater resources is much more even. In the territory of Hungary, 3.3 km$^3$ of water infiltrates into groundwater aquifers annually, with an additional 0.16 km$^3$ of groundwater flowing in through national borders.

Hungary's geothermal conditions are rather favourable. This means that in our country, it is sufficient to drill into smaller depths for the temperature to rise by 1 degree than in other parts of the world. In about 80% of Hungary's territory, thermal water of a temperature over

30˚ Celsius can be obtained. We must, however, exercise caution in the exploitation of thermal water, as this resource is only recharged slowly; therefore, its use must be limited for the sake of sustainability. Groundwater quality is still generally favourable, which allows its versatile utilisation. 94-95% of Hungary's drinking water is gained from groundwater resources. Shallow groundwater, i.e. the first aquifer, however, is contaminated in several places. At the same time, contamination has also occurred in also some 5-6% of deep groundwater and karstic water, which limits their utilisation.

## WATER UTILISATION

Recently annual average water abstraction for different purposes reaches 5 300 million m$^3$. Far the most amount of water is used by the energy industry for cooling (*Table 1*). The second largest user is the agriculture with its 510 million m$^3$ abstraction from surface waters for irrigation and fishery.

*Table 1. Annual water abstraction from surface waters*

| | [M m$^3$/y] | % |
|---|---:|---:|
| Municipal | 30 | 0.6 |
| Irrigation | 110 | 2.1 |
| Fishery | 400 | 7.5 |
| Industrial | 70 | 1.3 |
| Services, construction | 300 | 5.6 |
| Energy industry, cooling | 4 100 | 76.9 |
| Bank filtered | 320 | 6.0 |
| **Total** | **5 330** | **100.0** |

*Table 2* shows that municipal usage is the dominant water abstraction from subsurface waters, which exceeds 57% of the country's total annual average abstraction. Significant portion (13.4%) of the water abstractions from subsurface waters is in the grey or dark side. That portion is an estimate of illegal water abstractions, which exceeds the legal agricultural use (irrigation and livestock combined).

*Table 2. Annual water abstraction from subsurface waters (without bank-filtered)*

| | [M m$^3$/y] | % |
|---|---:|---:|
| Municipal | 400 | 57.2 |
| Irrigation | 10 | 1.4 |
| Illegal | 94 | 13.4 |
| Livestock | 50 | 7.2 |
| Industrial | 55 | 7.9 |
| Services, construction | 40 | 5.7 |
| Energy industry, cooling | 50 | 7.2 |
| **Total** | **699** | **100.0** |

## WASTE WATER DISCHARGES

Except for power plants and fish ponds, the economy uses groundwater substantially besides surface water, even though it is less justified by the rate of recharge. In some regions, we exploit our resources almost totally. These regions are the followings: between the rivers Danube and Tisza, the Nyírség, and in the case of karstic waters, the Transdanubian Mountains and the Buda thermal karstic system. The annually abstracted amount of groundwater is 699 million m$^3$, of which 565 million m$^3$ will flow into surface waters as treated waste water (*Fig. 1*).

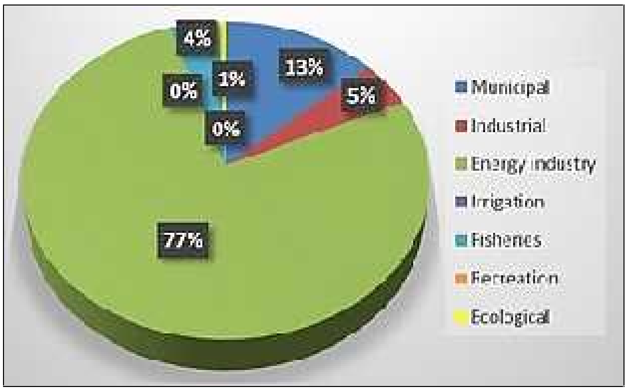


*Figure 1. Distribution of waste water discharges into surface waters in Hungary*

## WATER RESOURCES AND CLIMATE CHANGE

Compared to the rest of the world, Hungary and the other countries situated in the Danube River basin have a solid access to renewable water resources; only the Czech Republic is water stressed (*Fig. 2*). Hungary has a 10 000-m$^3$/capita/year availability. However, Hungary's internal freshwater resources are among the lowest compared to the other countries, about 6 billion m$^3$/year. This is an important argument why Hungary should be considered vulnerable in the region. Luckily, due to the rich groundwater resources, drinking water supply is granted.

As for climate change, Hungary is affected by an increase in air and hence water temperature, prolonged droughts and low flow situations coupled with worsening flood trends and changes in water runoff patterns. Since the Hungarian water sector depends strongly on regular rainfalls and temperature-related consumption, these changes may jeopardise the good condition of the infrastructure and revenue gains in the near future. Though measures have been taken, these are such challenges that are hard to face not only on a professional level.

One of the expected consequences of climate change is that water resources become less and less accessible. Despite the reduction of available resources, the level of demand remains and is even expected to increase. In other words, there will be more and more demand for water, which could be only satisfied to a limited extent or not at all. Therefore, in order to avoid water shortages, it is necessary to know both the resources and the future demand in more detail than currently, as it is shown in *Fig. 3*. In addition, more conscientious water management is in order. We must aim for:

- increased water retention for better utilization of our waters
- more economical and more efficient water use
- gradual improvement of the status of our waters
- a higher quality water and water utility service and the implementation of stormwater
- management with affordable tariffs

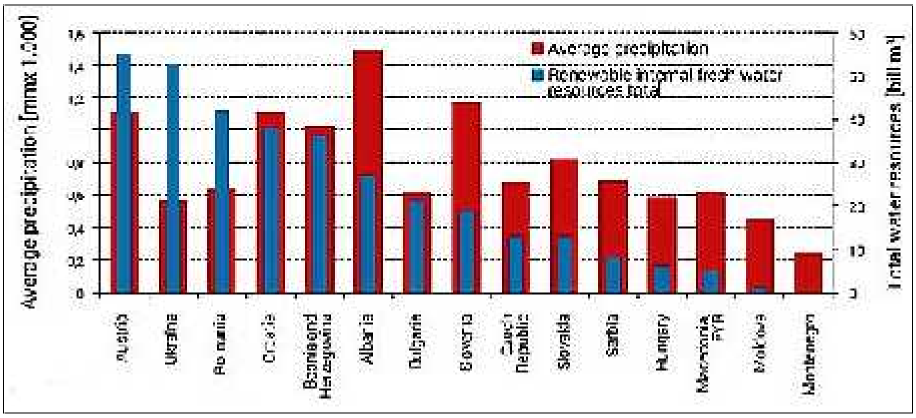


*Figure 2. Average precipitation and renewable internal freshwater resources for the Danube region countries*
*(Source: FAO AQUSTAT 2015)*

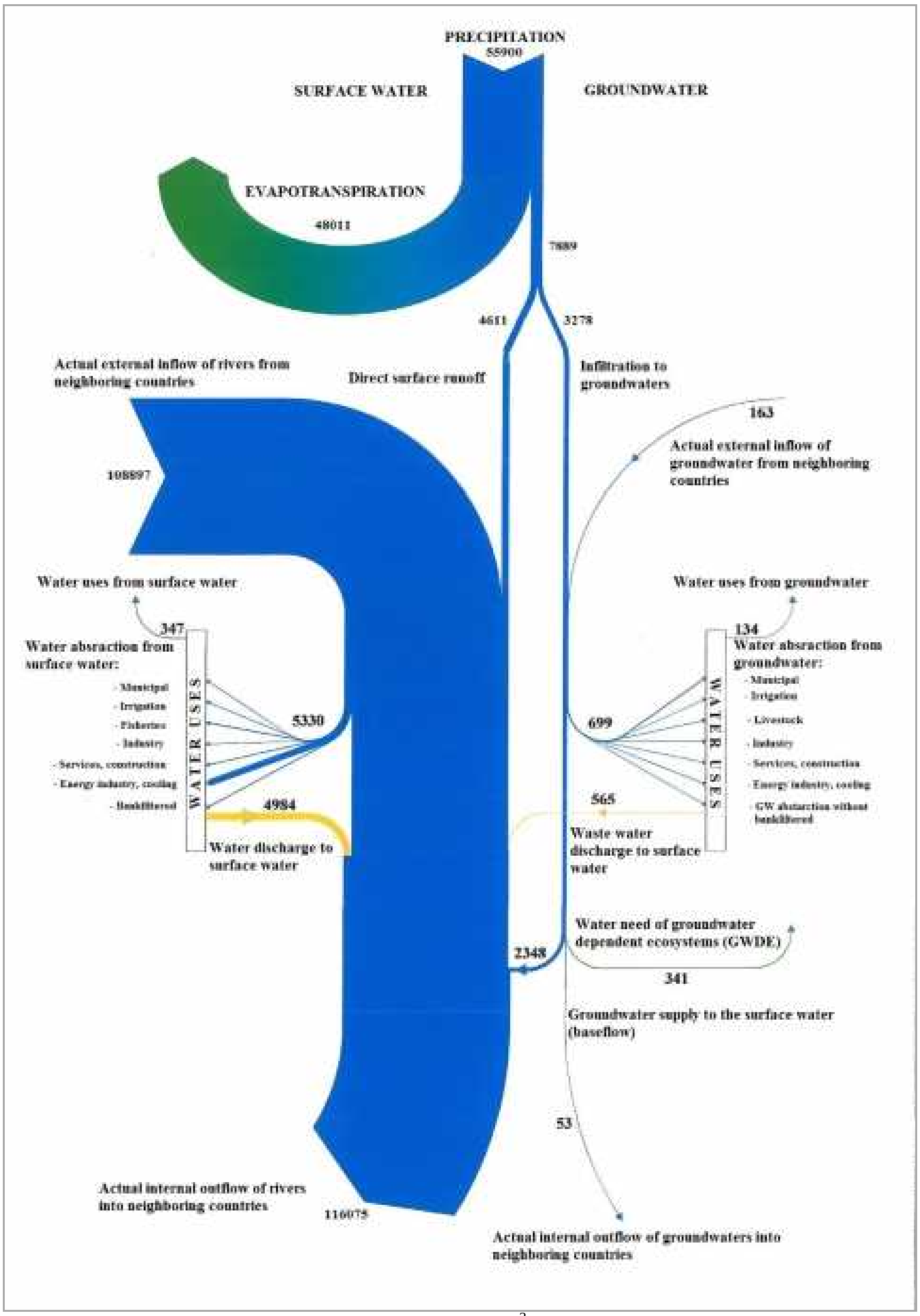


*Figure 3. Water balance of Hungary [million $m^3/y$] (based on data for 2001-2010)*

It is the task of water management to assist adaptation with 21st century tools, mitigating the harmful effects of extreme phenomena, while providing society with the indispensable water evenly distributed in space and time, when and where necessary.

## THE DEVELOPMENT OF PUBLIC WATER SUPPLY IN HUNGARY

### Historical background

The technical and economic conditions for the construction of a public water supply network appeared and spread during the 17-18th centuries, typically in the big cities of industrialised Western Europe. Due to belated industrialisation, this process only started in Hungary in the second half of the 19th century.

*Figure 4. Danube water vendor on the streets of Pest at the end of 19th century*

Industrialisation not only demanded water supply for industrial plants but also made it necessary to provide healthy drinking water to the ever-increasing urban population (*Fig. 4*).

The first waterworks in Hungarian cities were built in the 1860s. With the advancement of civic democracy, the social demand for water was met with a growing attention on the part of local and national politics, and the issues of drinking water supply were approached with appropriate legal, financial and organisational decisions. A typical example of this was the construction of the first version of the Pest waterworks in 1868.

As a result of developments, a unified authority was also created by the end of the 19th century and the country was ready for a widespread public water supply. In the framework of the Ministry of Agriculture, the Institution of Civil Engineering was set up in 1879 for the design and management of building small-scale water supply facilities. In 1890, the National Water Construction Directorate was founded under the direction of the Ministry of Agriculture. The Directorate was responsible for the water supply of cities and so the waterworks were built in Pécs, Miskolc, Sopron and Győr at this time.

In Pest, organised water supply began in 1868. The first pump house stood in what is now Kossuth Square, but it had to be closed because of the building of the Parliament. The construction of the new waterworks was started in Káposztásmegyer in 1893. The building work was done in several phases and was completed in 1904. Following the turn of the century, the metropolitan waterworks of Budapest was able to supply drinking water for 1 million inhabitants (*Fig. 5*).

*Figure 5. Water tower on Margaret Island, 1913*

At the same time, in the initial phase, 23 km of drinking water network was built in the capital, which has by now increased to 5000 km.

Considering the development of medical science, hygiene practices were also changing. The urban population demanded larger and larger amounts of clean water for everyday life. In some ways, the increase of urban population and the process of urbanisation can be regarded as driving forces of water network development. In cities and towns interested in building waterworks, it was usually the civil engineering offices that were commissioned to design them.

According to the summary of the National Public Health Engineering Service in 1898, there were altogether 244 bigger or smaller drinking water networks in 166 towns and villages. This meant that, together with drilled wells, altogether 4 million people, 23.8% of the population were supplied with healthy drinking water. By the First World War, the number of supplied inhabitants rose to about 5.5 million. This period was the first intensive phase of the development of drinking water supply in Hungary.

In the 1930s, there were further significant developments around Lake Balaton. As of 1935, the water supply was centrally managed by the Ministry of Industry, which enhanced development and more organised construction. By 1944, there were central waterworks in 27 towns and 32 villages *(Nagy 2013).*

### Development after WW2

The actual development of water supply in Hungary started in the second half of the 20th century. There was a wave of large-scale waterworks development in the early 50s, and it was typical of the whole sector that the works were completely state owned. Parallel with this, the demand for water grew significantly.

To meet the growing demand in Budapest, two surface water purification plants were built in 1957-1967: one in the territory of the main plant in Káposztásmegyer and the other on the Danube bank by the Northern limits of Újpest. The result of the fast implementation of these investments was the fact that by 1971, the rate of homes connected to the public drinking water network reached

83%. Another consequence was that by creating community water supply, the difference between the amount of produced water and invoiced water became greater; that is, the utility gap opened wider and wider. After the political transition in 1989, one of the greatest tasks was to put an end to this. When Hungary joined the European Union, these issues were brought more to the foreground. Consequently, the current and future key issues of the public water supply service will inevitably be modified *(Bethlendi and Füstös 2008).*

In other parts of the world, there are huge problems in the water supply area. According to different international surveys, 25 thousand people die daily due to water shortage in different corners of the world and two and a half billion people have no access to healthy drinking water. Besides, the freshwater supply of the world is continually shrinking.

The decrease of freshwater poses a problem in developed countries as well, which is partly the result of an increase in consumption and partly of human activity that adversely affects the environment.

In Hungary, the situation is slightly better, but we still face challenges. Although the country's available water resources are above the European average, we are poorly supplied with locally generated surface water. The vast majority of our surface waters come from the catchment area of the Rivers Danube and Tisza outside our national borders and also leave Hungary in due course.

The situation is much more favourable with respect to subsurface waters, as there are protected water resources in the Kisalföld (Small Plain) and the Nagyalföld (Great Plain), which are significant even in European comparison.

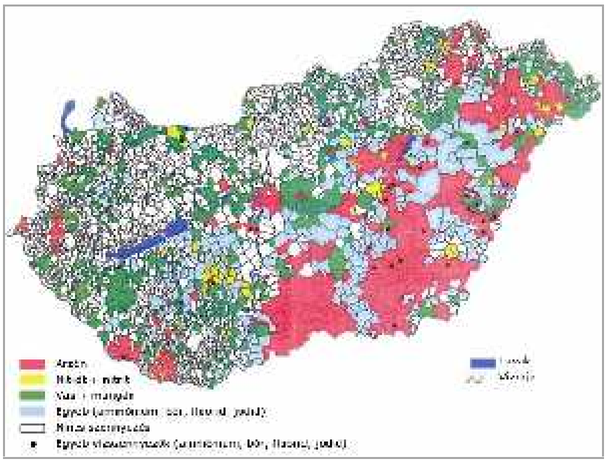

*Figure 6. Regions of subsurface water resources where the water quality does not conform to EU standards for drinking water use*

*(Note: Arzén: arsenic; Nitrát + nitrit: Nitrate + nitrite; Vas + mangán: Iron +manganese; Egyéb (ammónium, bór, fluorid, jodid): Other (ammonium, boron, fluoride, iodine); Nincs szennyezés = no pollution; Egyéb vízszennyezők: Other water pollutants)*

**Challenges for the future**

- to secure the operating and long-term water bases
- to solve the quality problems of drinking water supply
- to gradually catch up with developed European countries with respect to sewage disposal and waste water treatment while also protecting our water base
- to develop a service structure appropriate to new regulations
- to develop a system of tariffs based on consumption and expenditure.

In order to achieve the objectives of community water management, the state must assume a greater role in the future. This would improve the asset management of water facilities and the condition of the water supply networks as well as compliance with EU regulations. Hungary must fulfil her obligations set out in the 98/83/EC Drinking Water Directive and fully implement the Programme for the Improvement of Drinking Water. (Key parameters are arsenic, boron, fluoride and nitrite. A further specific key parameter for Hungary is ammonium given in the Government Decree 201/2001 (25 October) on drinking water quality requirements and monitoring procedures).

Two regions that needed the most to implement the necessary developments are the Northern Plain and the Southern Plain Region (Fig. 6), where in booth regions major water quality improvement measures were carried out lately. Some 1.2 million people are affected in the Southern Plain, 700 thousand in the Northern Plain and 260 thousand in Southern Transdanubia. All in all, two hundred communities take part in the programme. In other regions of Hungary, fewer communities are affected by drinking water quality problems. In the above-named regions, drinking water is supplied from subsurface waters and the arsenic, boron, ammonia and fluoride present in it are of geological origin. As of 2007, the implementation of investments is aided by tenders called for by the Environment and Energy Operative Programme. Investments have typically been and remain to be co-financed from three sources: EU funds, government budget funds and mandatory own contribution.

Due to Hungary's special hydrogeological feature, our drinking water supply is largely based on water bases installed on subsurface water resources. This feature constitutes a priority task at the same time. A substantial part of water bases is situated in vulnerable geological environments. Therefore the Government, in its Decree 2249/1995 (31 July), took measures to protect drinking water bases. This scheme has been in operation since 1996.

In Hungary, the standards were EU conform regulations even before joining the European Union. In 1998, the limits were further tightened. Drinking water quality needs to be improved for over two million people in nine hundred communities in Hungary (*Fig. 7*). The EU has extended the deadline for the implementation of the Programme to Improve Drinking Water Quality (*URL1*).

At the time of the political system change in 1989, the length of the total water network in Hungary was 48 500 km and that of the sewage system was 12 500 km. 74% of homes were connected to the public water supply network and 42.5% to the sewage system. By 1990, 83% of homes were connected to the public water supply network and by the end of the millennium, their ratio reached 90.8% (*Fig. 8*).

*Figure 7. Number of settlements in Hungary without drinking water appropriate to public health requirements,1995-2011*
*(Source: KSH – Hungarian Central Statistical Office)*

In Budapest, their ratio is over 98%, and in other cities it is nearly 95%, which means that the difference in supply between types of communities has decreased significantly. Today, over 85% of homes in villages are also connected to the public water supply network and their ratio exceeds 82% even in villages smaller than 200 inhabitants *(KPMG and MAVÍZ 2015).*

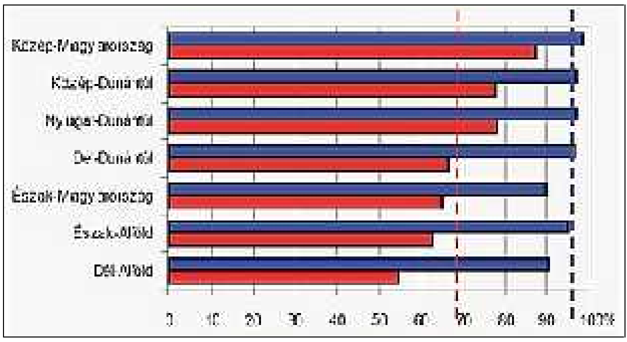


*Figure 8. Utility gap -2011*
*(Note: Közép: Middle; Magyarország: Hungary; Dunántúl: Transdanubia; Nyugat: West; Dél: South; Alföld: Plain*
*Blur bar: % of residential homes connected to public water supply system; Red bar: % of residential homes connected to sewerage network;*
*Source: KSH – Hungarian Central Statistical Office)*

Besides supplying the capital city, the Metropolitan Waterworks provides the water supply of European standards for a further 21 communities around Budapest. Currently, there are more than 700 drinking water wells in operation on Szentendrei Island, Csepel Island, Margaret Island and along both banks of the Danube, which can provide up to 1.2 million $m^3$/d of drinking water.

**Changing water consumption of the population**

Compared to the end of the 1980s, water consumption has decreased by about 50%. The reasons for this are a change in the consumption habits of the population and the increase of tariffs.

In Hungary, a person uses 90 litres of water a day on average. However, data vary according to the size and the extent of the supply in a given community (*Fig. 9*). Today, the average daily consumption is 150-160 litres per person in Budapest, 120-130 litres in other cities and 50-70 litres in villages *(Eördöghné Miklós Mária 2013).*

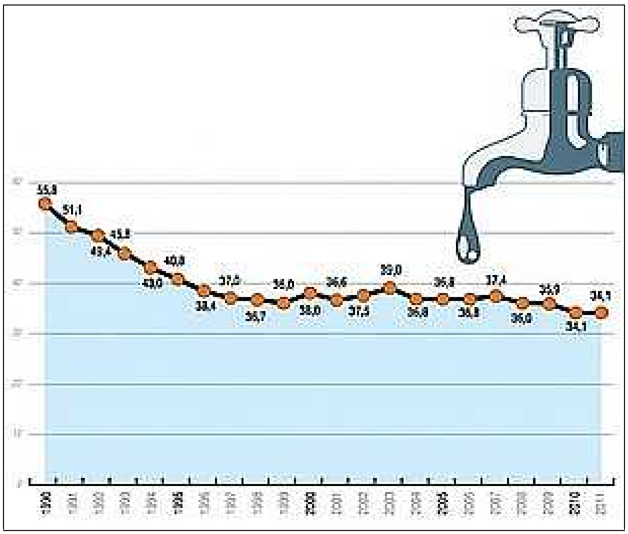

*Figure 9. Per capita annual water consumption in Hungary, [m3]. (1990-2011)*
*(Source: KSH – Hungarian Central Statistical Office)*

**The organisational structure of water service providers**

Before 2011, 400 service providers were in operation in Hungary. Such huge fragmentation resulted in chaotic circumstances in the water service sector.

The overwhelming majority of service providers are exclusively nationally owned and four companies are partly owned by foreign service providers with minority shares. As a consequence of legal regulations, services in the future can only be provided by water utility companies that meet the criteria laid down in EU-directives. The work of the 46 service providers that were given permission by the Hungarian Energy and Utilities Regulatory Office are continually monitored from technical-economical and legal aspects. The permissions issued are revised by the Hungarian Energy and Utilities Regulatory Office every three years. Of the companies that have been granted permission to operate, 5 are in majority state ownership, 2 are majority owned by the capital city Budapest and the remaining 39 are majority owned by municipalities (*Fig.10*). The sector directly employs approximately 20 thousand staff *(KPMG and MAVÍZ 2015).*

*Figure 10. Water utility companies in Hungary, January 2016*
(Source: DRV – Transdanubian Regional Waterworks)

### The changing of utility service tariffs

Following the law on the water utility sector coming into effect in 2011, municipal governments lost their pricing authority. Recommendations for official tariffs are made by the Hungarian Energy and Utilities Regulatory Office to the Minister responsible for the supervision of the sector. Taking the recommendations into account, the Minister establishes the tariffs applicable to the different water utility providers, water utility systems and water utility service providing activities in a decree (*Fig. 11*).

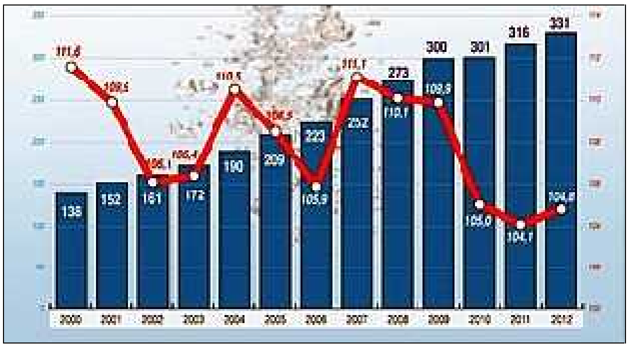


*Figure 11. Average water tariffs in Hungary, 2000-2012*
*(Note: Blue bar: national average water tariff; Red line: consumer price index, %; Source: KSH – Hungarian Central Statistical Office)*

According to the Water Framework Directive of 2009, the ceiling of affordability for water tariffs in Hungary is 2.5–3.5% of income. However, in less developed areas of the country, expenses spent on water exceed 5% of incomes. The situation is further worsened by great development programmes that are already in progress as well as restoration works that cannot be delayed any longer. It is impossible to significantly expand the water utility service with depressed prices. Service tariffs, parallel with the tariffs of other utilities, have risen gradually, which has also contributed to a drastic drop in water consumption. On the basis of statistical analyses, 70% of tariffs is fixed costs spent on operational expenditure and only 30% depend on actual consumption.

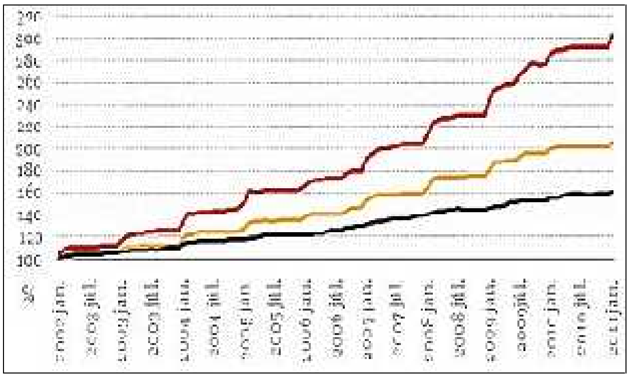

*Figure 12. Inflation and the changing prices of water/wastewater services, 100%=December 2001*
*(Note: Red line: Wastewater; Yellow line: drinking water; Black line: Inflation. Source: Hungarian Central Statistical Office)*

According to a statement by the Central Statistics Office, wastewater treatment tariffs have tripled in the past decade and water rates have doubled since December 2001 (*Fig. 12*). That is to say, both services have become more expensive, significantly above the inflation rate.

## ASPECTS OF SUSTAINABILITY

The Agenda for Sustainable Development, which came into force on 1st January 2016, identifies 17 goals (Sustainable Development Goals – SDG) that determine the global development priorities to be achieved in the next 15 years. Among these goals, SDG 6 represents the availability of clean drinking water and sanitation for all. The approach targets not only third world countries but also the developed world, including Hungary and its closest environment: the Danube catchment area.

According to a report made by the World Bank, the main area for the water sector sustainability is determined: it consists of twelve major activities, which are measured and compared to one another for each country (World Bank 2015). It is a very useful summary of the output that has been achieved in more powerful countries and the challenges to be overcome in the rest of the region. On the other hand, this report is an important milestone, as water services play a major role in achieving equality in society, which is the ultimate purpose of international trends.

### Access to services

In Hungary, situated in the heart of the catchment area of the second largest river of Europe, the access to safe drinking water and proper sanitation is high, compared to the rest of the world. Though environmental awareness was not high during the communist era, water supply systems developed fast. By 2011, 97% of homes were connected to the public drinking water supply and drinking water quality in general conforms to national standards. Due to changes in recent years, fragmented water service providers merged, resulting in an important rearrangement, whereby the quality of service has further improved. However, the steady decrease of the population, especially in rural areas and remote towns, has resulted in an oversized infrastructure that lacks the financial means to maintain its service, let alone invest in development. Another important demographic factor is that, contrary to the other Danube region countries, the majority of poor people live in urban areas, where access to piped water is more widespread.

Although almost 80% of the population in the Danube watershed use flush toilets, only 66% are connected to public sewage networks (*Fig. 13*). In Hungary, these values are 93% and 80% respectively, which is the result of development in waste water treatment that has shown significant improvement in recent years (e.g. construction and operation at the Budapest Central Wastewater Treatment Plant). In general, there is a close relationship between the use of flush toilets and the connection to public sewage networks. In the capital, the rate reaches 100% and the central and western regions in general have high representation as well. The situation is more challenging in remote rural areas of particularly small villages (100-200 inhabitants). In the Eastern part of the Danube catchment area, the situation regarding waste water treatment is even more challenging, especially where waste water treatment has only recently been introduced.

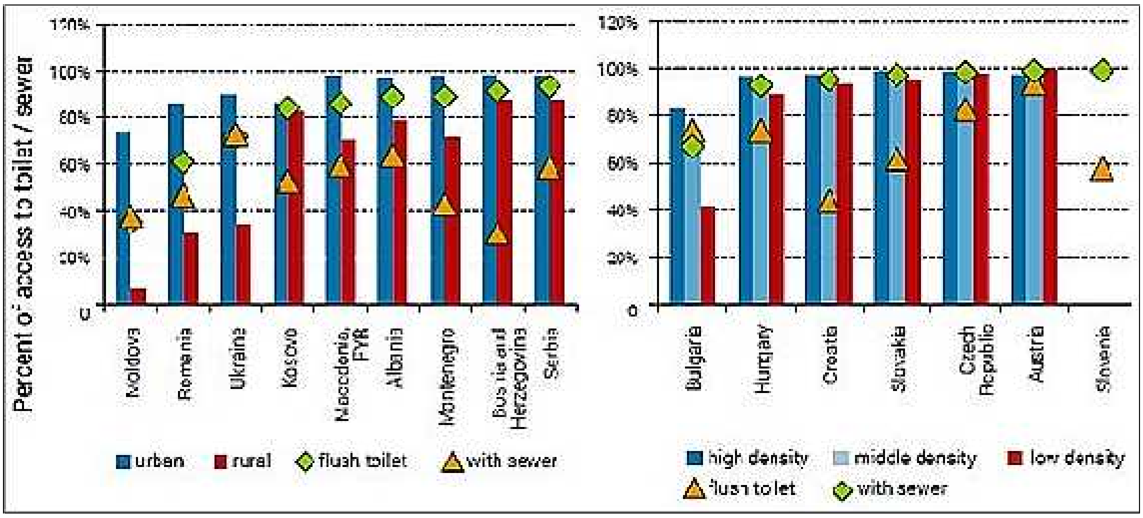


*Figure 13. Percent of population with private flush toilets (left) and sewer connection (right) in the Danube region countries*

**Performance**

Customer satisfaction strongly correlates with service quality, though only few privately managed utilities conduct customer satisfaction surveys directly. In Hungary, according to the results of independent surveys, customer satisfaction stands at 77%, above the regional average of 63%. Another customer-related indicator is cost: water-related services are affordable to the average consumer. Thresholds are set below 5% of income and nowadays there is centralized tariff control, resulting in the so-called "overhead decrease". The average collected water tariff in Hungary is $5.35, which is in the middle range compared to tariffs in countries of the region. As for tariff-setting trends, there is no specific methodology in Hungary. The process is under development: it is only applied by communities with newly established networks. An important aspect to consider would be the implementation of the rate of return, which has been applied in some countries. As for the present situation, municipal governments seem to prefer lower tariffs to higher profits.

From a financial aspect, the second important shortcoming is that the region is still far from implementing the principle on cost recovery outlined in the Water Framework Directive. Only operational expenditure is covered by tariffs. Investments are generally supported by public funds and external transfers. The amount of regional investments is about €3.5 billion, significantly below the target, needed to achieve EU and national targets. According to the survey mentioned above, Hungary is lagging behind regarding the average annual investment share of the overall sector financing with only 15%, while 38% compared to the Danube region and 42% in Europe. If we also take into account that the capita/year value stands only at 13€, the picture becomes even darker. Throughout the past years, there has been an above-inflation increase in the costs. This tendency has resulted in a significant increase in tariffs, which were the major source to cover operational costs in Hungary until 2013.

The performance of the sector is below international standards; especially overstaffing and non-revenue water pose significant challenges. As of non-revenue water, the situation in Hungary can be declared as consolidated, with 6.1%, which only slightly rises above the determined good practice level and is well under the average 14% for EU member states and 35% for the Danube region, where the lack of proper metering and water balancing is still a problem for most service providers. Because it is directly related to the condition of the network through the water leakage factor, maintenance and reconstruction play a major role. Hence, the relationship between utility efficiency and the economic development of the area becomes even more apparent.

The issue of staffing level is an on-going topic, mainly in locally owned public utility companies. Staff productivity is 1.7 for 1000 inhabitants, which is almost equal to the regional average, but it is still above the international good practice level and the EU member state value, which is set for 1 employee per 1000 inhabitants served. This is an indicator where the economy of scale could play an important role in the future. On the other hand, another indicator that helps to determine a company's sound commercial practice is the collection ratio. Traditionally, the western part of the Danube Basin represents a high rate, above or even outperforming 100% with Austria 105%, Slovakia 116% and Romania 112%. Hungary, with 94%, is below the average of the values in the Danube countries. However, it is not absolutely clear how the collection ratio is calculated.

On the other hand, another indicator to determine and compare the performance of the water sector in the region is WUPI (Water Utility Performance Index). This index defines three major categories (coverage, quality and management) and ten sub-categories with each score ranging from 1 to 10. With a score of 81, Hungary is in the upper third and above the regional average of 69.

## CONCLUSION

We can conclude that the Hungarian water utility sector performs well compared to the other countries in the region. On the other hand, it must be clear that there is still the possibility for further improvement if we compare the above indicators with international standards and good practices on a national and regional level. As a whole, information flow is underperforming, which hinders effective decision-making in the sector. Legal support needs to be strengthened to help create a more reliable background. The distribution of EU and state funds should be limited according to established needs and its effect should be monitored in the long run, even after the completion of major investment projects.

Setting up a minimum requirement for utilities to gain permission to operate and limiting access to state or EU funds would ensure a more important financial emphasis. Benchmarking reports would be useful for the sector when lobbying for greater support. A favourable trend that many companies have recognized in recent years is that water-related business risk is considerable and directly linked to economic development. This new mindset could help start up corporate water stewardship in the future. This incentive urges companies to implement sustainable water management practices and to broaden their line of action, thus accelerating the process of sustainability sensitization.

Looking at the bigger picture, water services are strongly related to the socio-economic milieu they are operating in. Therefore, a mutual correlation exists between water sustainability and economic development. By applying a more holistic approach, important momentum can be gained to raise the living standard of all, which is the ultimate purpose.

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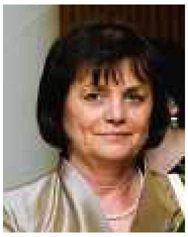

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# Sanitation in Hungary

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**Dedication**

Our article is dedicated to late Dr. Pál Benedek (1924-2016), who was the director of Water Quality Protection Institute of VITUKI until he retired, and founder of the Hungarian water quality control system. Dr. Pál Benedek's exceptional professionalism, credible and kind humanity remains eternal example for us.

**Abstract**

The conscious, systematic planning of sewerage system started in the last third of the nineteenth century in Hungary. Nowadays more than 80% of the dwellings supplied with public drinking water has been connected to sewage networks and at least 75% of the wastewater treatment plants has biological stage wastewater treatment. The sustainability and integrated water management teaches us a new way of thinking. The cost-effective and environmentally friendly use of integrated water management systems is becoming more and more urgent to ensure sustainable development and adapt to global climate change. The treated wastewater, rain water and sewage sludge have to be considered as source of power and energy, and this approach, attitude should be learnt by our generation as well as the next generation.

This article outlines the Hungarian sewerage and wastewater treatment history from the Roman times to present days through turbulent World War times and discusses the likely main development directions in the sector, which would match the climate change and sustainability challenges.

**Keywords**

Sewage, wastewater treatment, integrated management of water, water reuse

## INTRODUCTION

The conscious, systematic planning of sewerage system started in the last third of the nineteenth century in Hungary. Nowadays, 85% of dwellings with public water supply is connected to the sewerage system and in 75% of wastewater treatment plants there is at least biological treatment. The sustainability and integrated water management teaches us a new way of thinking. The cost-effective and environmentally friendly use of integrated water management systems is becoming more and more urgent to ensure sustainable development and adaptation to global climate change. The treated wastewater, rain water and sewage sludge have to be considered as source of energy, and this approach, attitude should be learnt by our generation as well as the next generation.

This article i) outlines the Hungarian sewerage and wastewater treatment history from the Roman times to present days through turbulent World War times, ii) provides an overview on wastewater collection and treatment practice and iii) reviews the most important achievements and daily problems on this professional field. Furthermore, most likely development directions of the sector and their connections to climate change and sustainability challenges are discussed, as well.

## WASTEWATER COLLECTION PRIOR TO WORLD WAR I

In Hungary the earliest data of wastewater collection is related to the fortresses of the Roman Empire. In some locations of Roman time remnants closed pipes made of stone transported stormwater and sewage to the nearest stream were excavated.

The Hungarian reform era in the middle of the $19^{th}$ century brought the first recognisable changes. Needs for sewerage systems have been forced partly by industrialisation and to a greater extent by the fear of cholera and plague epidemics spreading almost completely unchecked from Western Europe in the second part of the $19^{th}$ century. Conscious, systematic planning of sewerage system started. The system implemented in the city London served as template for Hungary, and unsurprisingly the first plans and designs were prepared by English engineers.

The first so-called „Local Legislation" was created, ending the earlier practice of ad-hoc construction works often resulting in chaos and flood risk. According to then time legislation, only the town itself was entitled to build pipelines, and, as the pipeline was being built, flats had to be connected to the system. Costs of construction had to be covered by the property owners living in the given street.

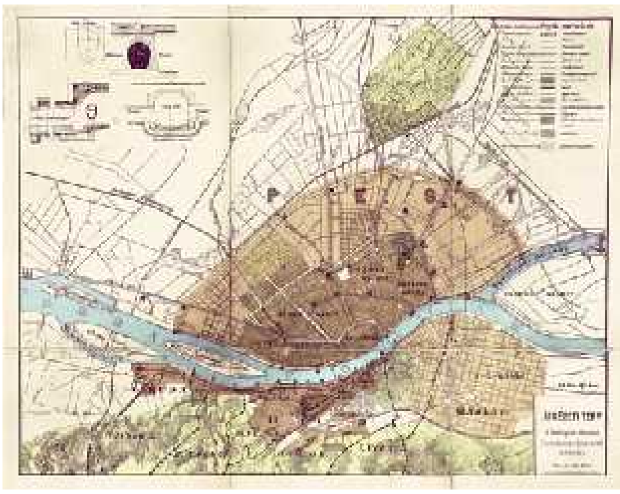

*Figure 1. The first sewerage map of Budapest (Source: Budapest csatornázása: Pest város 1847. évi csatornázási szabályrendeletének 125 éves évfordulójára 1972)*

The final third of the 19th century was a reflection period for the intellectuals in the fields of public health and technical professions. After a longer period of debate, they came to the conclusion that wastewater collection had to be implemented using combined sewers. The pioneer role of József Fodor, public health university teacher must be emphasized, who utilised his experience acquired during his visits to London and Berlin.

*Figure 2. Construction of the Pumping station in Ferencváros (Source: Budapest csatornázása: Pest város 1847. évi csatornázási szabályrendeletének 125 éves évfordulójára 1972)*

The first plans were prepared for Budapest,  the capital of Hungary that became a single city with the unification of Buda, Óbuda and Pest in 1873. The actual construction begun in 1892 and the Pest collection network on the left side of the Danube (flat terrain) was finished by 1910 (*Fig. 1-3*). Pipes of the Buda side (right bank) were constructed utilising the hilly terrain, using mainly open ditches which discharged directly into the Danube. Establishment of heavy-duty pumping stations that were powered by steam-engines was a significant improvement. These pumping stations were able to convey stormwater, as well. The pumping stations were equipped with screen in order to filter coarse floating and suspended materials.

*Figure 3. Construction of sewerage main in 1910 (Source: Budapest csatornázása: Pest város 1847. évi csatornázási szabályrendeletének 125 éves évfordulójára 1972)*

The example of the capital was followed primarily by other cities and towns with hilly landscape utilising the possibilities of gravity. By that time the treatment of wastewater was not on the agenda, partly because it was thought that the discharged sewage was "consumed" by the river via dilution, and partly because it was considered that wastewater was an important food source for fish. Some cities guessed – based on foreign, that time mostly from German examples - that sooner or later some kind of treatment would be necessary, thus the planners already designated the location of treatment plant during the construction of collection system.

In the meantime, the notion of using wastewater for irrigation purposes, originating from England, started to spread,. For the first time, based on a German example, the city of Arad constructed an irrigation area for a population of 60.000 people in 21 hectares. Unfortunately the operation that wastewater irrigation system was stopped soon, due to a miscalculations regarding the necessary capacity and consequent overload.

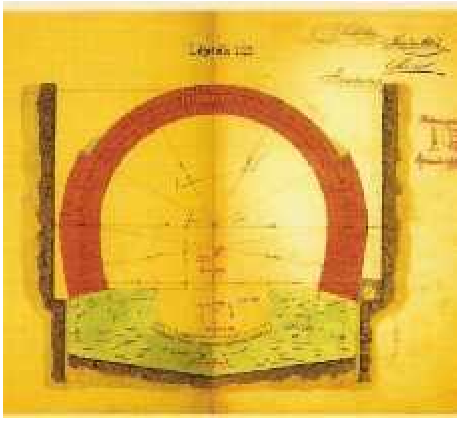

*Figure 4. Special cross-section of Nagykörút sewerage main (Source: Budapest csatornázása: Pest város 1847. évi csatornázási szabályrendeletének 125 éves évfordulójára 1972)*

Several cities followed Budapest in constructing sewerage (*Fig. 4*), primarily the ones that were able to get loans in order to finance construction works, and the ones that already had some kind of public water supply. At around 1910 almost 40 cities had closed sewerage system and 7-8 cities started the construction of them (*Csatornázás Fejlődésének Története 2008*).

After the Austro-Hungarian Compromise of 1867 was signed significant developments started in industrialisation, urbanisation and housing conditions that generated needs for further developments regarding water supply and wastewater collection. Primarily county towns and towns located near to the capital started to construct their sewerage systems.

Due to World War I the rapid development came to a halt. In the years following the war, after Hungary seceded from Austria, the main task was to consolidate and reorganise the national administration. Unfortunatelly for a long time, the institutional background - that could have been the driving force in developing public utilities - was lacking.

## WASTEWATER COLLECTION AND TREATMENT BETWEEN THE TWO WORLD WARS

In the first third of the 20th century villages did not demand public water supply, not to mention wastewater collection. On one hand, the necessary financial power was not available in the villages, on the other hand aversion to new ideas, insistence on traditional way of life also contributed to the negative attitude towards public utilities.

The approach in wastewater treatment remained the same. The „highest" level of treatment were screens installed at some outfalls on the riverbank. In 1936, in order to protect the drinking water supply of Budapest, a compound settling basin (Imhoff tank) was established in the town of Vác (30 km from Budapest upriver). Its removal efficiency was ~20% regarding suspended solids and 9% regarding organic matter.

The first plan of an actual wastewater treatment plant in Hungary was prepared in 1936, the aim was to treat the wastewater of the industrial zone of North Budapest. The facility would have contained only mechanical treatment technologies, but the project was cancelled due to preparations for World War II. Only the stormwater pumping station was constructed.

Between the two World Wars public water supply (mainly in cities) had significantly greater development opportunities. In the second quarter of the $20^{th}$ century, between 1930 and 1945, the capacity of water works increased by 235 000 $m^3$/d, while the treatment capacity showed a much smaller growth of 22 000 $m^3$/d, thereof 15 000 $m^3$/d was destroyed during World War II.

Sewerage development was hindered by the effects of World War I and subsequent huge territory loss (2/3 of the country) and later by preparations for the new war. The main advocates of sewerage were the densely populated cities, where the blocks of flats were the dominant type of homes. Smaller towns, "garden cities" and villages were able to handle and dispose wastewater in-house, so there was no need for costly sewerage system.

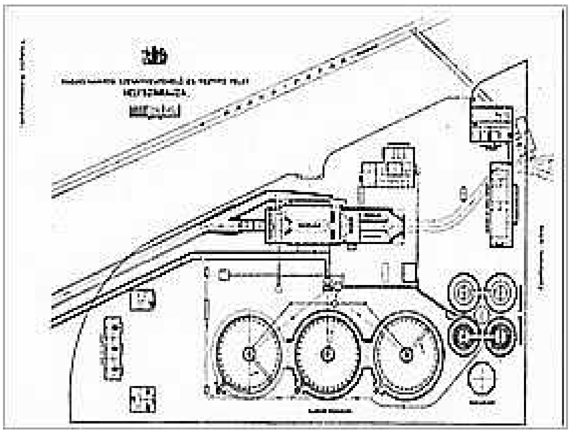

*Figure 5. The I. development stage of Angyalföld wastewater treatment plant (Source:Lesenyei 1940)*

Most of the cities utilised the storm-sewer network to manage wastewater. However, these sewers rarely discharged into treatment plants, more frequently the nearest stream or river received their load, without treatment. The country had 15 wastewater treatment plants altogether, most of them only with mechanical pre-treatment, according to today's terms (*Fig. 5).*

Concerning the years just before World War II, there were 120 towns and cities with more than 10 000 inhabitants in the country. Thereof 12 had only storm-sewer network and 26 had sewerage system. Altogether 4.17 million people lived in these cities and 2.25 million people enjoyed the „luxury" of wastewater collection. Looking at the whole country, at around 20% of the population accessed sewerage systems. The total length of the sewers was 1 781 km, thereof 105 km was used exclusively for wastewater.

The five years of World War II changed many things. The plans under development stage were never implemented, the investments that had already begun have been completed only partially or not at all.

After 1945 the territory, population, political and social structures of the country changed. The most important tasks after the war were clean-up and securing provisions for everyday life.

## WASTEWATER COLLECTION AND TREATMENT AFTER WORLD WAR II

In the first three years after the war the reconstruction of public utilities had begun. simultaneously with repairing damages caused by bombings and artillery, reconstructing blown up roads, bridges and railways, Only in Budapest the pipe was caved in at 153 locations and 60 km pipe was plugged. The bombing destroyed the central pumping station as well(*Fig. 6).* Significant part of the former employees scattered, so new workers had to be hired and trained. The bigger cities in the country suffered similar damages.

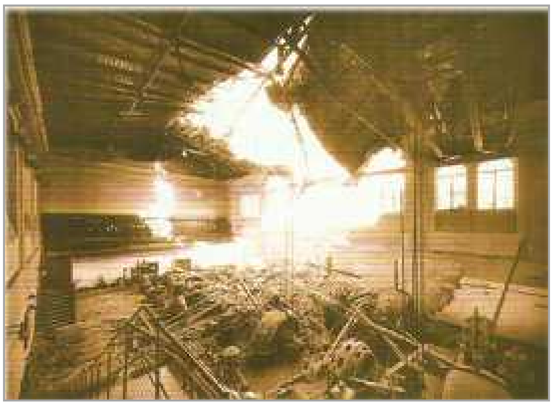

*Figure 6. War damages (1944-45) (Source: Budapest csatornázása: Pest város 1847. évi csatornázási szabályrendeletének 125 éves évfordulójára 1972)*

One of the first measures was the new institutional framework set up. As a cornerstone of this process public property status of water and establishment of a unified water service were declared in the Constitution. In 1948, under the Ministry of Agriculture, the National Water Management Authority was formed. Scope of duties of this organisation included technical aspects and licensing of drinking water supply and sewerage systems, while the Ministry of Social Welfare was responsibility for public health issues.

Every waterworks, wastewater collection systems and wastewater treatment plants were placed under state supervision, in order to provide operation based on the same principles for better quality. This practically meant the beginning of nationalization for this area of strategic importance *(Fig. 7)*.


*Figure 7. Status of sewerage level at the end of 1948 (Source: Gov. Decree 9170/1948)*

The gap between provisions of drinking water supply and sanitation started to grow after World War I and continued again from the 1950s. During the development of residential areas in cities and industrial districts, wastewater collection become a requirement, but wastewater treatment could not keep up. Essentially a secondary gap appeared between collected wastewater released into receiving waters only through screen and grit chamber and the amount of wastewater going through biological treatment.

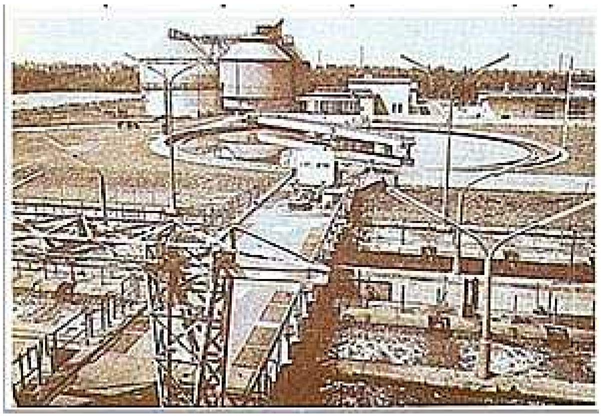

*Figure 8. The first activated sludge wastewater treatment plant, South Pest (1965) (Source: Budapest csatornázása: Pest város 1847. évi csatornázási szabályrendeletének 125 éves évfordulójára 1972)*

*Figure 9. The combined biological devices of the Inotai-Juhász type Balatonlelle plant (1973) (Source: A szennyvíztisztítás története 2011)*

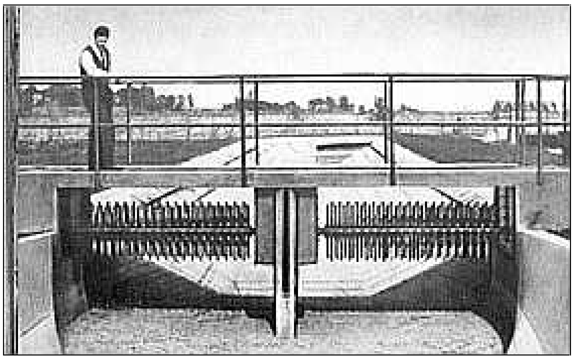

*Figure 10. Oxidation ditch with Käfig rotor (1966) (Source: A szennyvíztisztítás története 2011)*

Biological treatment started in the late 1960s, first only in priority areas (*Fig. 8 and 9).* Lake Balaton was one of those areas, as it was considered national treasure being a popular destination for tourists. Provision of drinking water supply was a priority here as well, but wastewater treatment plants with biological treatment were built here in a quick succession to protect the water quality of the lake (e.g. Keszthely, Siófok, Balatonfüred).

Regarding technology, the low load so-called activated sludge comprehensive treatment plant became dominant, where organic matter decomposition and sludge stabilisation took place in the same basin. Oxidation ditches („Pasveer" ditch) required significant amount of land, and were replaced by basin technologies enabling more depth with the spreading of more effective aerators (vertical aerators).

At the same time, the first wastewater treatment plant of Budapest was built, utilising the results of pilot plant experiments, to protect the South Budapest industrial area and the holiday resorts (priority area) of the Soroksári Danube branch. The South Pest Wastewater Treatment Plant was a high load treatment, using activated sludge treatment process, with mesophilic digestion.

There was no education related to wastewater treatment technologies until the mid-1960s in Hungary. This field was represented by foreign engineers and some Hungarian engineers who studied abroad (Berlin, Zürich). The first book was translated by a technical officer (Major József Héthársi (Hauszman)) from German to Hungarian. Later a foreign company's guideline was released that contained instructions for planning activated sludge process. Géza Öllős was commissioned in 1963 to set up the Department of Water Supply and Sanitation in the Technical University of Budapest, where his main task was laying the groundwork for the new technical field and developing methodology for education.

The Ministries established supporting institutions for their development duties. The former leader of the National Water Authority, Undersecretary Imre Dégen successfully integrated every institutions of the water sector under the National Water Authority (NWA), thus forging one of the ablest organisation in the country. He initiated the foundation – among others – a research institute (VITUKI), which became well-known and respected research centre as well as an engineering design institute (VIZITERV) for supporting the development goals of the

NWA. Soon, booth institutes became internationally renowned as well. In VITUKI Dr. Pál Benedek (outstanding leader of the Water Supply and Sanitation Department), later leader of the Water Quality Protection Institute) created the domestic practice of activated sludge treatment process and laid down the theoretical foundations for water quality control. He was co-founder of the International Association on Water Pollution Research and Control (IAWPRC), the present-day International Water Association (IWA), where he was honorary member until end of his life. His successor in VITUKI - László Somlyódy academician – held the position of Chair in the above mentioned international organisation. International reputation of the Institute was demonstrated by the fact that it was commissioned by the World Health Organisation (WHO) to conduct major research tasks, and in addition to that researchers arrived from many countries to prepare their PhD thesis in the Institute. In the beginning of the 1970s, the leader of the Institute managed to secure 40 WHO scholarships for researchers, engineers and manufacturers to study the technological devices and novelties of water supply and sewage in the developed countries. The acquired knowledge and experience significantly speeded up the domestic developments. Countless patents and innovations proved how successful this investment was.

The new sewage pumps preventing plugging imported and manufactured in cooperation by the Swedish Flygt company significantly improved the sewage sector. The usage of these pumps enabled the existing gravity sewer mains to connect more distant districts in a city that contributed to the practice that for one city or town, there is a single wastewater treatment plant, with the exception of the capital.

The new solutions generated new problems. In the long force mains wastewater putrefied and this way the engineers, scientist and operators started to work on solving problems like smell, corrosion and other effects.

Until the mid-1980s development of drinking water supply was the priority, but parallel to that the need for improved wastewater treatment became more and more emphatic.

In Budapest (population almost 2 M) the sewerage development programme of the Northern industrial zone and residential areas started in the 1970s. The first development stage of the North-Budapest Wastewater Treatment Plant was constructed (amid arguments and political interference) using Soviet plans and designs. Despite numerous technological and mechanical engineering problems, this was a step forward and served as a basis for both quantitative and qualitative development.

After the first development stage (1982) two more stages followed and finally 1.035 M PE (200.000 $m^3$/d) capacity was established, that contained biological treatment, removal of nutrients and mesophilic digestion. It was completely self-sufficient regarding heat and could produce 80% of the electricity necessary for operation per annum, utilising the urban organic waste.

In the same time, wastewater treatment plant construction started for 10 bigger cities in the country in connection with the Gabčíkovo–Nagymaros Waterworks programme. The development concept considered the following aspects: i) locations with higher ratio of wastewater collection had priority, ii) the reservoir of the planned hydropower plant must be prevented from receiving untreated wastewater and lastly, iii) protection of water sources (riverbank filtration) of Budapest must be increased. Out of the designated 10 cities, five were located on the upper reaches of the Danube (Győr, Komárom, Esztergom, Tatabánya, Oroszlány). The other five cities that the Programme considered were Miskolc, Debrecen, Pécs, Szolnok and Szeged. The latter two cities located along the Tisza River could not make the first stage of evaluation due to the lack of financial resources. Until the political changes that started in 1989-1990 construction of treatments plants along the Danube was more or less finished.

Water supply and sewerage tariffs were set by the National Tariff Authority. Water tariff, as a type of workers allowance, was a political question, and just as the price of the bread it was not allowed to follow inflation. Biggest losses were made by spa corporations, where the price of each sold ticket must have been supplemented with the same amount from water tariffs. Waterworks had no choice but to start with side-business activities (construction, manufacturing pumps, pipes, etc.) to cover their operational costs. The developments forced by the leaders of the sector were financed using financial resources for maintenance and amortisation and this led to a deterioration of the condition of facilities.

Because of water tariffs were artificially kept low, excessive water consumption was widespread in the industrial sector and in households too. This affected the capacity of water works and wastewater treatment plants. Hydraulic overload of wastewater treatment plants often reached 20-40%.

Between 1945 and 1990 the ratio of population connected to wastewater collection increased from 18% to ~42%.

*Figure 11. North-Pest Wastewater Treatment Plant, III. development stage (1.035 million PE ,200.000 $m^3$/d) (1982-2010) (Photo: FCSM Archive)*

## WASTEWATER COLLECTION AND TREATMENT AFTER THE POLITICAL CHANGES OF 1989-1990 AND NOWADAYS

After the national parliamentary election in 1990 stable democratic institutions developed and negotiations to join the European Union had begun. In 1st May 2004 Hungary became the member of the EU.

After 1990 drinking water supply was the priority again resulting in high quality water supply network for each and every settlement in Hungary by the end of 1994.

Regarding wastewater treatment and collection, the ISPA and PHARE programmes provided support for EU candidate countries.

By the beginning of the 1990s it became clear that policy change will be necessary in professional and economic sense. Since 80% of collected wastewater was generated in Budapest and the 22 county towns the Government approved a new programme for the wastewater treatment capacity development for the capital Budapest and 22 additional county towns in 1994. The implementation of the governmental programme was funded mostly from ISPA and PHARE support of the EU. One example is the Nyíregyháza WWTP (*Fig. 12*).

*Figure 12. Nyíregyháza Wastewater Treatment Plant, 160 000 PE (2001) (Photo: Nyírségvíz Ltd Archive)*

In the frame of the „új Magyarország"(New Hungary) development plan and the ongoing „Széchényi 2020" development programme, the Cohesion Funds available with EU membership provided support for handling problems of wastewater collection and treatment in settlements over 2000 PE.

The most significant development of this period was the Central Wastewater Treatment Plant of Budapest (CWWTP) and completion of wastewater collection network for the entire city of Budapest (Fig. 13).

*Figure 13. The Central Wastewater Treatment Plant of Budapest (1.35 million PE) (Photo from URL1)*

The (CWWTP) was the biggest element of the Living-Danube project. Prior to the operation of this plant, only 50% of the wastewater was treated in Budapest. This resulted in severe contamination, and threatened several indigenous fish species in the Danube. With the new treatment plant and with the development of collection network, practically complete wastewater collection and treatment have been achieved in Budapest.

Nowadays, drinking water supply network is available in every settlements in Hungary, and 95% of the households are connected to it. *Fig. 14* shows the improvement in the ratio of households with access to drinking water supply and wastewater collection network. As a result of the developments between 1990 and 2012 new wastewater infrastructure was built in many settlements, this way the gap between drinking water supply and sanitation had been narrowed to 85%.

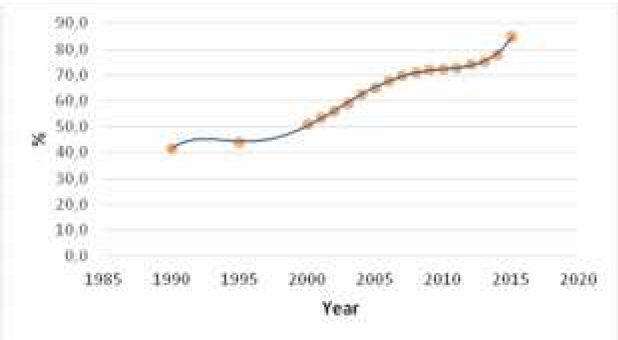


*Figure 14. Percentage of dwellings connected to public water supply and sewerage networks (Source: URL2)*

Besides, the quality of treatment has significantly improved after 1990. While in 1990 54% of the collected wastewater went through only mechanical treatment before reaching the recipient, by 2013 in 75% of the treatment plants had tertiary treatment stage *(Fig. 15).*

The leap between 2000 and 2015 brought some undesirable effects as well. EU members must comply with the Urban Wastewater Treatment Directive. Albeit wastewater collection and treatment of settlements over 2000 PE almost reached the level defined in the Directive, the situation of small settlements below 2000 PE still unsolved for most of them.

In 1991 the daily water consumption was 160 l/person/day, nowadays it is only half of it, causing serious operational and sustainability problems.

As a result of the developments significant wastewater treatment capacity was established. However, the capacity is just partly utilised (especially the hydraulic capacity) (*Fig. 16*) because of the decreased water consumption, slow rate of connecting the households to the network and the oversized capacity.

As all around the world, utilization of sewage sludge is a great challenge in Hungary. Despite the fact that concentration of pollutants in the released sewage sludge do not exceed the limits set by EU. For bigger wastewater treatment plants energy recovery is a natural option, but the changing legal and financial environment is a major stumbling block to any form of sewage sludge utilisation on farmlands. The disposal of 190-200 thousand tons of sewage sludge dry matter per annum is a critical issue these days.

In 2011, after the Act No.CCIX of 2011 on water public utility service came into force, the transformation of structure of water utility sector has begun. The number of water utility companies has been decreased from 400 (2011) to 42 (2015). In the current economic environment (utility cost reduction, tax burdens without financial resources), with shrinking revenues and growing expenditure the water utility sector reached its limit concerning room for increasing efficiency. By 2014, because of utility cost reduction and introduction of utility tax the sector became loss-making (*URL3*).

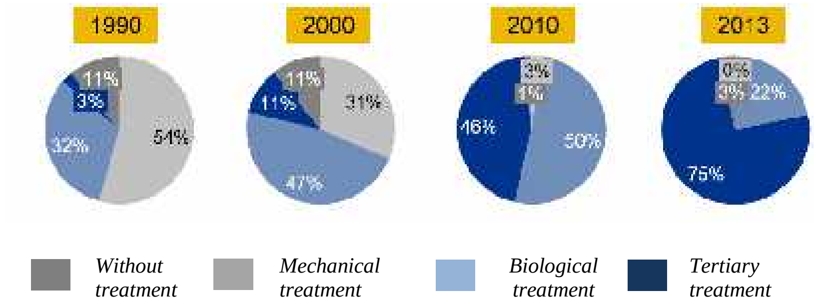


*Figure 15. Ratio of different wastewater treatment level (in percentage of total treated wastewater) (Source: URL3)*

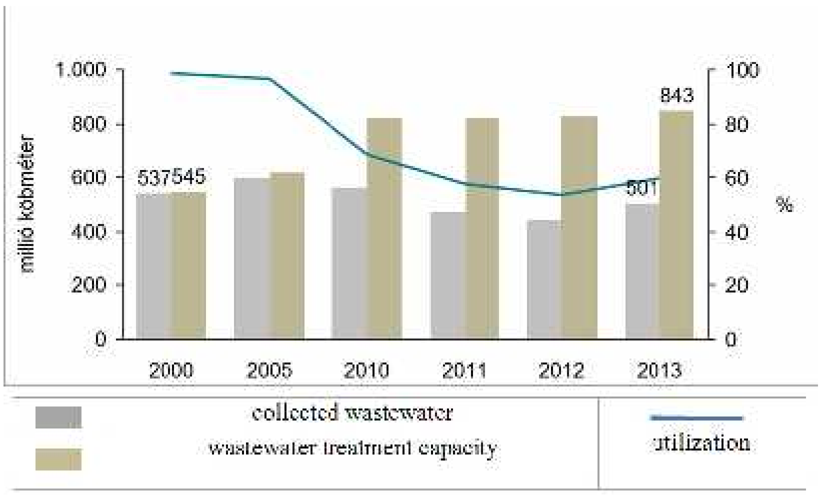


*Figure 16. Wast water treatment capacity of Hungary, amount of treated wastewater and utilization of the capacity between 2000 and 2013 (Source: URL3)*

## COMPARISON OF WASTEWATER COLLECTION AND TREATMENT WITH EU COUNTRIES

Based on EUROSTAT data (2013) *Fig. 17.* shows the ratio of households connected to wastewater collection network and Fig.18. shows the ratio of households connected to wastewater treatment plants.

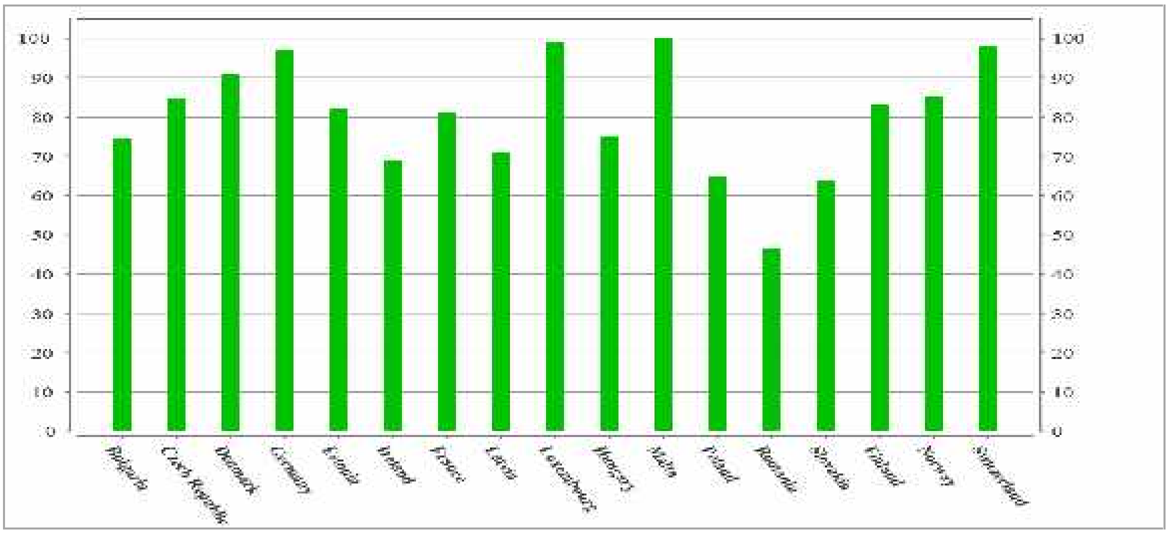

*Figure 17. Population connected to urban wastewater collecting system, in some EU Member States (Source: URL4)*

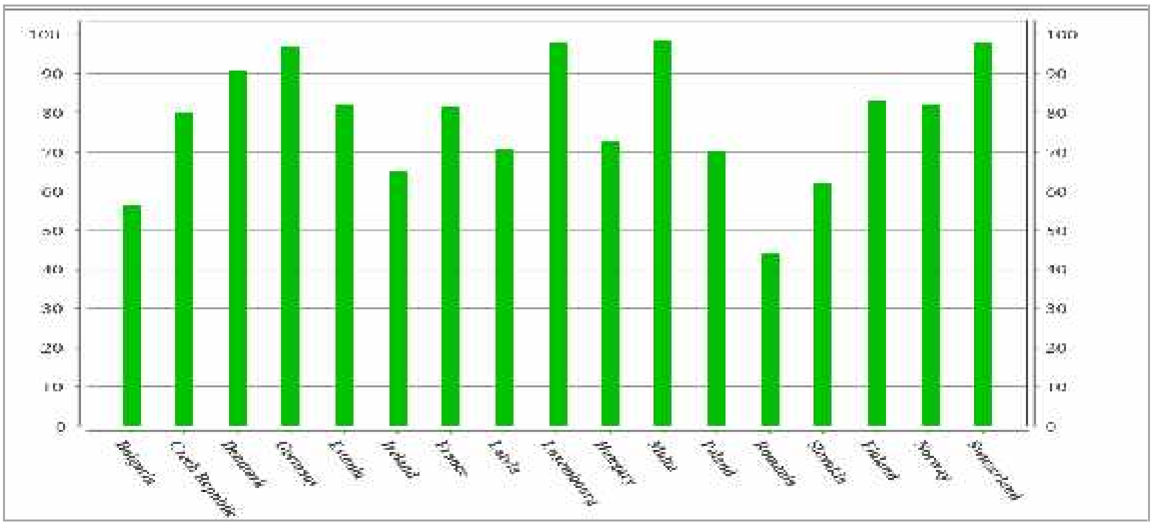


*Figure 18. Population connected to wastewater treatment plant, in some EU Member States (Source: URL4)*

In 2013, ratio of households connected to wastewater collecting system in Western European countries significantly exceeded the ratio of Hungary, but compared to the former socialist countries of Eastern Europe, the situation is better only in the Czech Republic.

## ASPECTS OF SUSTAINABILITY AND INTEGRATED WATER RESOURCES MANAGEMENT

UN Sustainable Development Goals 2015-2030 define the following tasks for public water sector *(Fig. 19)*:

Goal 6: Ensure access to water and sanitation for all

Goal 11: Make cities inclusive, safe, resilient and sustainable


*Figure 19. Sustainable Development Goals for public water sector (Source: URL5)*

Looking at the SDGs, Hungary goes in the right direction with regard to providing clean drinking water and sanitation, taking into account the available water sources. Appling integrated water resources management systems (*Fig. 20*) becomes a more and more urgent task in order to facilitate sustainable development and to support the adaptation to effects of climate change.

Politics realised the significance of the problem and they entrusted the experts with the task of carrying out necessary work to facilitate integrated water resources management.

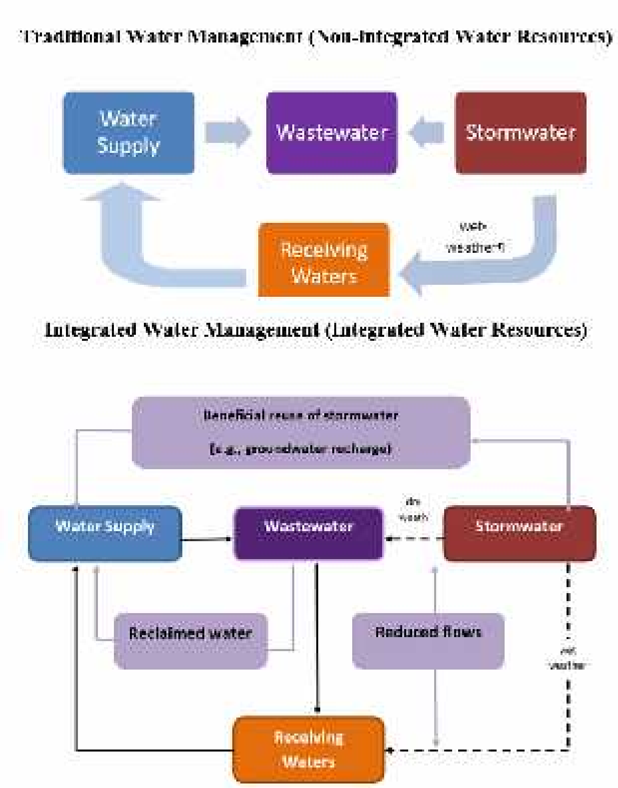


*Figure 20. Traditional versus Integrated Water Management (Source: URL6)*

Wastewater, storm water, drinking water and sewage sludge must be looked upon as resources that together form our integrated water resources.

### Expected developments and trends

Hungarian development goals must be in accordance with UN Sustainable Development Goals and relevant EU directives, strategies and recommendations. The followings are of fundamental importance: Europe 2020 Strategy, European Climate Change Programme, and the EU's 7th Environment Action Programme until 2020. Hungarian Adaptation of these documents happens through the National Climate Change Strategy (2008-2025) (NÉS), and the 4th National Environmental Protection Programme.

Mid-term goals of Hungary are *(OVF 2014)*):

- Reducing and preventing pollution of the environment
- Protection and sustainable use of natural resources; water retention, storage
- Promoting green economy
- Promoting regional cooperation
- Development of urban wastewater collection and treatment in the fields of technology, engineering and automation
- Promoting sewage sludge utilisation as a renewable resource
- Facilitating the move towers green economy characterised by low greenhouse gas emission
- Increasing the efficiency of energy consumption and utilisation of resources
- Increasing the share of renewable energy sources
- Increasing resource efficiency of energy sources, sustainable use of resources
- Sustainable use of properly treated wastewater, as a basic element, in regions characterised by drought
- Developing the field of agri-environment, with special attention to soil conservation
- Promoting sustainable agricultural use of sewage sludge
- Environmental technology innovation
- Finding adequate solutions for settlements where wastewater collection cannot be constructed efficiently, taking into account domestic conditions (cost efficiency, operation, financial support, sewage sludge disposal, etc.)

## FUTURE OUTLOOK

Quote from Charles Darwin: *„It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is most adaptable to change."*

Following Darwin's thoughts, we must adapt our water utility and sanitation to the climate change and to the economic rationality required by sustainability. We have to rethink old habits to deal with new challenges. The expected developments and trends in some decades to come outline concrete tasks for us.

### Implementing complete wastewater collection and treatment based on sustainability

Based on current trends, complete wastewater collection and treatment in Hungary is expected by 2040 (*OVF 2014*). Especially for settlements below 2000 PE, elaboration of a legal-technical background that favours simple but environment-friendly solutions is very important. In case of bigger wastewater treatment plants the goal is reusing treated wastewater.

### Wastewater treatment plants are tomorrow's energy and nutrient recovery plants

The task of wastewater treatment plants is to keep the environment cleaner, but during the process they use significant amount of energy and chemicals, while treatment and disposal of sewage sludge is a problematic issue everywhere.

Hungarian scientists answer these challenges with a patented technology. With this process, beside significant recovery of carbon, nitrogen and phosphorus, up to 50% reduction in the amount of sewage sludge, and 25-30% reduction in the plants energy consumption can be achieved. Nowadays, wastewater treatment gets more complex year by year. This new Hungarian innovation contributes to sustainable wastewater treatment with this patented technology.

The patented technology uses controlled hydrolysis to decompose the excess sewage sludge in a thermophilic, microaerophilic bioreactor. During the process, organic material will be released as volatile (short-chain) fatty acids, ammonia and ortho-phosphate. The reduced amount of sewage sludge can be treated using anaerobic digestion or in a biogas plant utilising its carbon content to produce biomethane. Dissolved materials are separated using membrane and with a distillation process, volatile fatty acids can be recovered as distillate, while nutrients (N, P, K, S) can be recovered as concentrate.

Volatile fatty acids are an important raw material for chemical industry, or can be utilised as readily biodegradable carbon source to enhance treatment efficiency, or to boost energy production.

Nutrients (that contain other important microelements for plants) get back into their natural cycle.

This way, our current wastewater treatment plants can be tomorrow's energy and nutrient recovery plants (*URL6*).

### Water reuse

Reuse of used water for irrigation, groundwater recharge or industrial purposes are well-known, decade-long practices. However, for many water users a simpler solution was to discharge treated wastewater into surface water recipients and to cover their water demand form surface water or groundwater. Water quality and quantity issues of the 21st century led us to the conclusion that wastewater treatment is part of an integrated, ecosystem-based water resource management system, where wastewater must be taken into account as resource.

*Figure 21* summarises the water quality produced by different levels of treatment. Economic efficiency and sustainability can be increased by using treated wastewater tailored to the future reuse.


*Figure 21. Water quality that can be ensured by different treatment levels (Source: URL7)*

### Sewage sludge as nutrient source

Sewage sludge production in Hungary is estimated to reach 272.000 t(dry matter)/year by 2040 (*Fig. 22*). Potentially sewage sludge could be utilised on 3.085.100 ha in the country, but in reality the ratio where sewage sludge usage is permitted by the authority is only 1.5%.

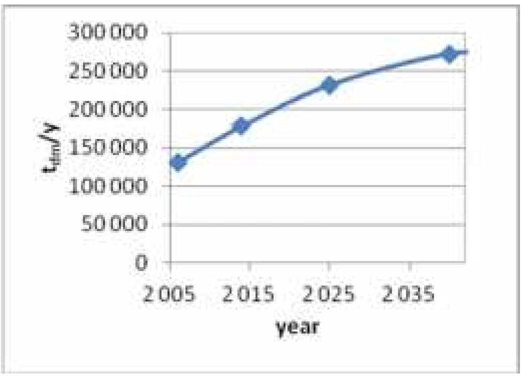


*Figure 22. Amount of produced sewage sludge in Hungary ($t_{dm}$/y) (Source: OVF 2014)*

In order to promote agricultural utilisation of sewage sludge as an excellent source of nutrients, current tender schemes, subsidies and the legal background need to be revised.

### Shaping attitude

*"A basic aim of environmental education is to succeed in making individuals and communities understand the complex nature of the natural and the built environments resulting from the interaction of their biological, physical, social, economic and cultural aspects, and acquire the knowledge, values, attitudes, and practical skills to participate in a responsible and effective way in anticipating and solving environmental problems, and the management of the quality of the environment."* (*Tbilisi Declaration 1977*).

We have to strengthen the approach in environmental communication and environmental education that water is a valuable resource. From nursery school through primary and secondary schools, family life can be a stage for environmental education and attitude shaping the sustainable management of water resources.

Sustainable development requires an approach that is able to handle challenges of the world looking at the whole system and able to reach and preserve the fine equilibrium among economy, society and environment.

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# The power of irrigation

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## Motto

„Only the state may be able to give an impetus to irrigation and being methodical is crucial in this work: the build-up of irrigation plants should not happen at random as it happened earlier in case of railway construction.” (Ferenc Kossuth)

## Abstract

Irrigation served determinant development of Hungarian agriculture in the 1970s and 80s of the past century. Focused production and the Soviet market made the stabilization of the agriculture possible. The „admission” and utilization of Western technology contributed to all these. „Irrigated cropping in the Tisza Valley” development program - as of the end of 1960s - initiated by FAO enabled committed professionals to gain the advanced knowledge of the world. As a result of it our researchers and professors occupied more positions simultaneously in international professional organizations.
Due to market loss and lack of organization the ownership change resulted in ceasing the operation of hundreds of acres of irrigation plants. Revival is less conceivable without the reformation of support and management conditions.

## Keywords

Production development, economic growth, technical revival, compensation of knowledge loss, hydrology

## INTRODUCTION

Reading, listening and watching recommendations of international conferences one might conclude that the summary of conference thoughts include generalities everywhere. These axioms refer to basic human needs, however they are difficult to construe by us.

Our ancestors settled down and stayed in the Carpathian Basin because they found here an environment rich in trees, fields and rivers. They had left the ancient regions (Ordos – plateau, Turan – plain) because of livelihood problems caused by climatic change and they found satisfying conditions here in the temperate zone. They did not formulate referendums but they acted. They did not declare what the 2nd World Water Forum conceived in The Hague in 2000 demonstrating the awareness of wealthy countries/nations: „Every human being, now and in the future, should have enough clean water for drinking and sanitation, and enough food and energy at reasonable cost. Providing adequate water to meet these basic needs must be done in an equitable manner that works in harmony with nature. For water is the basis for all living ecosystems and habitats and part of an immutable hydrological cycle that must be respected if the development of human activity and well-being is to be sustainable.” (*World Water Council 2000*).

This paper intends to dicuss i) why irrigation is important for the Hungarian agriculture, ii) how irrigation issues were handled in the past century, and iii) what would be recommended to do to improve agricultural profitability and production security using irrigation, especially in the most drought exposed Tisza Valley region.

## THE EVOLVED RATIOS

The growth of the human population resulted in permanent utilization of global water volume. Low reserve is available for achieving the set goals. With a little exaggeration we can say that the ratios are distributed almost to „molecules”. While we are striving for respect for human rights we are facing the utilization of the full capacity of continents. The developed world has already used up its reserves *(Fig. 1 and 2)*. In regions with developing economy there is a minimum difference between the data of year 1990 and 2025.

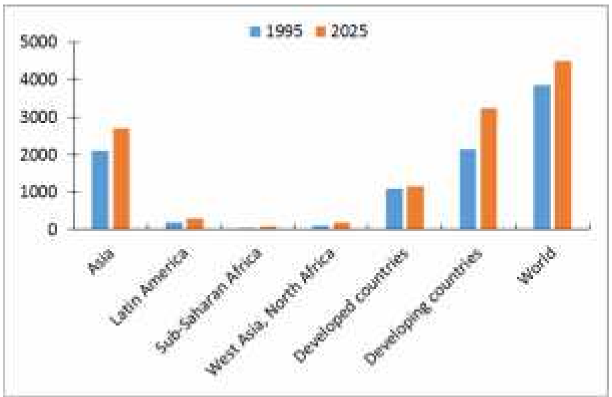


*Figure 1. Total water withdrawal by regions [km$^3$]*
*(Source: Author’s estimate and www.impactwater.org)*

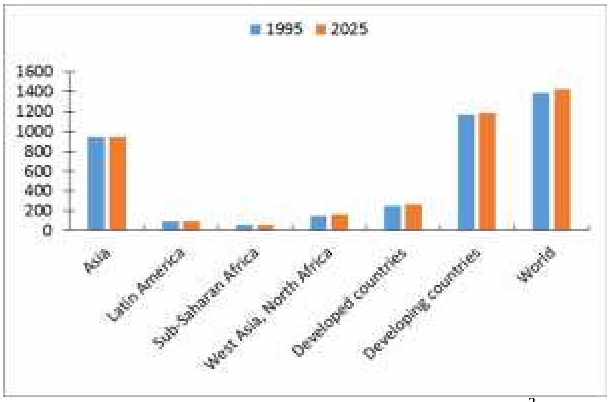


*Figure 2. Irrigation water usage by regions [km$^3$]*
*(Source: Author’s estimate and www.impactwater.org)*

Water resources available and used up annually is mostly suitable for the supply of current population. The difference would be totally utilizable for a more humane supply of people living in extreme poverty. But the income of national economies is not sufficient for the necessary developments. Realizing this economic reason people who are expecting bleak future are leaving their homeland (mother country) in the hope of a better living. With previous investments an almost fair method of water distribution was established where they are heading for.

The knowledge of resources in itself is not enough. Efforts must be made for the formulation and working out of optimal developments. The role of responsible decision-makers requires great caution in the event of all changes. Perhaps it is true also for them what true is for an engineer following a resolution: Knowledge, Ingenuity (seeing behind the scenes), and Integrity.

## HUNGARIAN POLICY-MAKERS' VISION IN THE 1960s

It is well-known internationally that Hungary has excellent climatic and soil conditions. All these enable its active participation in feeding the world. Besides production volume the production of quality goods is an equally important aim. The increase of crop yields is based on the coordination of production conditions and factors affecting yields. The most significant production conditions are: proper agricultural techniques, sufficient amount of organic and inorganic fertilizers, plant protection, optimal water supply, introduction of the production of intensive varieties etc. In order to increase production plant breeding, nutrients and water supply have major roles. When the *production factors* – aside from water – are in optimum, water becomes the key factor of yield increase and the application of irrigation necessarily occurs. The best production areas of the country are located in the valley of River Tisza. However, water scarcity occurs in these areas during the years (*Fig. 3 and 4*). This led to the discovery that elimination of water scarcity occurring during the growing period can happen by the construction of reservoirs.

The capitalist form of economy between the World Wars I and II made also necessary the irrigation water supply of peasant smallholdings. For this purpose the building of Tiszalök Barrage had been started but its construction could be completed only after World War II in 1954. With its construction the water supply of the south-east region of the country surrounded by the three-branch Körös River has been solved through the East Main Canal and Berettyó River. Many people make critical statements and approach to the barrages with negative feelings. Although the low precipitation in the growing period and its extreme temporal distribution can be counteracted only with the use of mainly winter water collected in reservoirs.

The following barrage built on River Tisza at Tiszalök, an other one, the Kisköre Barrage was implemented with the same aim. It is well known that 300 mm rain may fall in the growing period in the middle of the Great Plain, while up to 500 mm rain may fall in the Western part of the country. Owing to this the total water demand of plants can be supplied with the irrigation of 175 mm water in addition to the natural precipitation in areas affected by water scarcity. The various water supply indexes, so the water scarcity in the growing period or the quotient of the potential evaporation and the expected precipitation, the aridity values verify the construction of the new barrage.

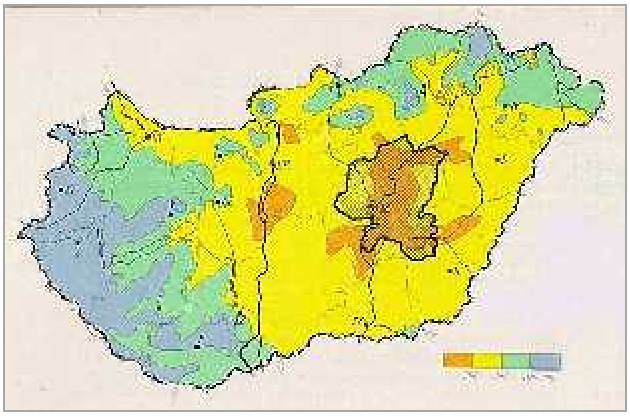

*Figure 3. Average precipitation of the growing period*

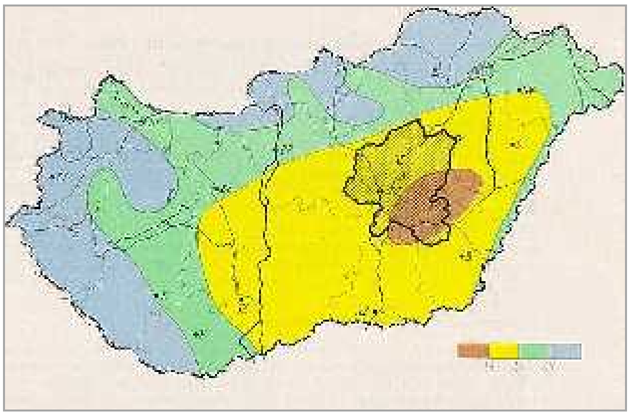

*Figure 4. Aridity map of Hungary*

### Reasons for the implementation of the Kisköre Barrage and its irrigation systems

Four-fifths of the Great Plain can be irrigated only from the River Tisza and its tributaries. The River Tisza is the main artery of the Tisza Valley river system. The extremely fluctuating natural discharge of River Tisza, the minimum flows occurring in months July – August and the water demand of the irrigations and fish ponds established until the end of 1965 demonstrate that irrigations cannot be developed further in the valley of River Tisza. Moreover, in years of drought the demand of the existing water uses cannot be satisfied. Water scarcity even increased during the last quarter of the last century because of the newer water uses realized in the neighbouring countries – in the territory of the then Soviet Union, Czechoslovakia and Romania. Therefore, in the central area of the Great Plain with the lowest precipitation, large-scale water supplementation establishments had to be constructed which increased the natural low summer discharge of River Tisza and satisfied the water demand being necessary for the further development of irrigation. That is why the Kisköre Barrage with the connecting reservoirs and irrigation systems were built. The fulfilment of the water management and agriculture development needs closely related to the economic development of Tisza Valley made the implementation of the Kisköre Barrage and its irrigation systems justified and necessary. (*Fig. 5*)

*Figure 5. A perspective view of the Kisköre barrage*

**Decisions concerning the implementation**

Tisza-canalisation and in its framework the plan for the establishment of a second barrage near Tiszasüly had already been a part of the preceding water management development plans and there had also been examinations for the more precise determination of its location. The first comprehensive technical study related to the establishment of the major structures of the Kisköre (2nd Tisza) Barrage was carried out in 1960. The (§ 23 of the) Act II of 1961 on the 2nd five-year plan instructs to start the investment preparation work being necessary for the implementation of the Kisköre (2nd Tisza) Barrage and its irrigation systems in the period of the 2nd five-year plan (1961-1965). The Government Decision of 1961 arranged for the preparation of the investment program.

The investment program proposal was finished in 1964 and the irrigable area through the barrage, the crop intensity, the irrigation water norms and the specific and total yield increase obtainable with irrigation on average were determined according to the position of the former Ministry of Agriculture.

The National Committee for Technical Development also examined the draft program and it stated in the conceptual study published in August 1965 that the establishment Kisköre (2nd Tisza) Barrage and its irrigation systems was considered important and significant for the people's economy and its implementation was timely.

Considering agricultural, production, technical, economy aspects and bearing capacity of the economy of the country, the General Directorate of Water Management broke down the investment into constructions stages and prepared the detailed implementation plan of the first building schedule. The government approved it and the Act II of 1966 on the 3rd five-year plan did the same.

So the decisions concerning the implementation were grounded by careful preparation, feasibility study, intermediate examinations and review consultations, economic studies, justification of the need for the investment and the position of the interested high authorities and councils. Accordingly the construction works of the first phase started.

**Solving water supplementation and water distribution**

After analysing more options the low summer discharges in Tisza Valley can be most economically increased with the canalization of River Tisza.

The regulation of River Tisza was already proposed by Count István Széchenyi in the middle of the 19th century. In his opinion five barrages would have been established in the River Tisza: Near Vásárosnamény, Záhony, Tiszalök, Kisköre and Csongrád. The longitudinal section of River Tisza indicates also the barrages of the Tisza canalization.

The studies showed that after the Tiszalök Barrage the implementation of the Kisköre Barrage and then the Csongrád Barrage should be foreseen.

The Tisza canalization is the main artery and backbone of the water distribution and supply system of Tisza Valley. As the river bed is the main canal of the system considerable savings are achievable and the available natural and stored water resources can be fully utilized. The Tisza canalization offers other long-term benefits too such as making the River Tisza navigable in its full length (600 km), its linking to the international shipping route and power generation with low prime cost (approx. 370 million kWh/year).

The Kisköre Barrage and Reservoir is a complex (multipurpose) water management establishment. Its primary purpose is to decrease the ever growing agricultural water scarcity and to ensure the water quantity being necessary for the development of agriculture. Its secondary purpose is to ensure the water quantity necessary for industrial development and for drinking water supply. The reservoir doubles the standard natural river discharge of August in the middle section of River Tisza and nearly triples the discharge being utilizable for water uses of Hungarian agriculture.

The direct impact area of the barrage and the major structures that can be supplied with irrigation water is 300 000 ha. Apart from this it ensures irrigation development opportunity in the systems of Körös-valley and Tiszalök with a further impact area of 150 000 ha.

In the direct impact area the irrigation plants supply three independent irrigation systems with irrigation water: The system along the backwater reach and the reservoir; and the systems of Nagykunság and Jászság (*Fig. 6*).

The so-called secondary major structures connected to the major irrigation structures supply water to the irrigation schemes, irrigation equipments and fish ponds established in the plants. Such secondary major structures are the main canals of each irrigation system and the reservoir Tiszafüred – Kócs.

The fulfilment of such requirements help people living in regions with adverse ecological conditions to survive. One example of this is Israel. The pressure of necessity caused to create successful agricultural businesses in the water scarce territory as a result of decades of hard work. (Of course there are other industries showing excellent development, for example the rise of Finland in manufacturing telephones). But in the field of water utilization the arid countries/states were and are advanced. California or Australia can be mentioned too but they have played the part of the „follower" countries recently.

*Figure 6. Location of the irrigation systems and their main canals*

Israel's success in the agriculture is the result of a long fight against tough aggravating circumstances but the country managed to establish a well-functioning agriculture with the well-chosen technical developments in spite of the limited water resources. People living under such conditions can be successful when they build up a thriving agriculture with farmers' and researchers' determination, when half of the country is a desert but they are aware that the real value of the soil always depends on the utilization method.

## THE OPPORTUNITY TO ACHIEVE HIGH PROFITABILITY

The agriculture plays an important role in the production of essential foodstuffs of the population in Hungary (bread from wheat, meat from corn). The produced wheat (in case of 5 million tons) covers the domestic demand of one million tons with a high degree of certainty. Further one million ton is also suitable for the dietary category. But the remaining amount increases the storage of feed.

It is undoubtedly true that the primary task of agriculture is the production of essential foodstuffs, the products being necessary for the so called mass catering. But in order to achieve high levels of human performance the human body must be provided with the optimal amount of minerals and vitamins too. For this purpose we must strive for a varied diet that can be achieved mainly with the consumption of horticultural crops. Most of the horticultural crops are short-lived. The plant cell structure is soft and it causes that the production conditions significantly affect its performance. If we create optimal conditions that is able to support the growth, producing harvest and achieving high nutritional value according to our expectation. To ensure this it is essential to satisfy the water demand of the plant. During the short growing period of vegetables the water supply must be ensured continuously because the periods with low precipitation prevent the achievement of the expected yield level in contrast with the woody plants. The water supply of the orchards has also high priority as the loads (frost effect, high temperature etc.) in the growing period may prevent the yield of the year but they weaken the opportunity of the preparation for the following year (sprout differentiation).

The irrigation of the horticultural crops is quite limited in Hungary (*Dobos 2014*). It is apparent in *Table 1* that a vegetable surface of 62470 ha was irrigated in 2013 but we get a sad value if we deduct 30000 ha of sweet corn field cultivated with field cultivation technology. Examining the yield of the irrigated areas it can be stated that the irrigated crops double the result. (There is an income of 1.15mln HUF / ha in the irrigated areas while the non-irrigated areas achieved 0.6 mln HUF / ha). It proves the gardeners' expertise in the optimal water application.

The results of the pomiculture can be seen in *Table 2*. Apple and sour cherry significantly stands out from the other varieties. The achieved results prove the positive effect of the irrigated cultivation as the non-irrigated orchard produced 1mln HUF / ha while the irrigated orchard doubled the amount (2.23mln HUF / ha).

## IRRIGATION OF THE HORTICULTURAL CROPS

Generally it can be stated that the water uptake of horticultural crops is very different. We can find quite drought tolerant ones (succulents), they are mostly ornamental plants but some herbs as well.

On the contrary vegetables requiring almost uninterrupted water supply feel well under other ecological conditions. Their 80-95% water content demands constant or uninterrupted water supply. Some of them prefer a turgor similar to hydrophytes. In their case we must provide water supplementation not only in the roots but also in the atmosphere. This activity is called just-in-time supply. In their case practically the infusion dosage must be carried out.

The temperate zone create relatively favourable conditions for woody plants as their foliage is able to „hide" enough water allowing for it to survive the transitional, shorter „water scarce" period without particular production decline. However fruit-trees or vine-stocks are able to maintain their living only cutting the assimilate production. Thus the winter water resource is not enough to achieve the expected economic results either in case of woody plants.

For that very reason conditions appropriate for the original place of production of the plant must be ensured. The technical devices for this are now available. Apart from the classical water supplementation the devices themselves are suitable to carry out irrigations with special purpose.

*Table 1. Production and regional distribution of open-ground olericulture in 2013 (Source: www.fruitveb.hu)*

| **Plant species** | **Total area (ha)** | **Irrigated area (ha)** | **Non-irrigated area (ha)** | **Yield volume (1000 t)** | **Yield volume irrigated (1000 t)** | **Yield volume non- irri-gated (1000 t)** | **Production value (mln HUF) total** | **Production value (mln HUF) Irrigated** | **Production value (mln HUF) Non-irrigated** |
|---|---|---|---|---|---|---|---|---|---|
| Open field paprika | 1 100 | 1 100 | 0 | 34 | 34,0 | 0,0 | 4 080 | 4 080 | 0 |
| Ground paprika | 1 600 | 1 500 | 100 | 12 | 11,7 | 0,3 | 1 800 | 1 755 | 45 |
| Open field tomato (indus-trial) | 440 | 440 | 0 | 32,7 | 32,7 | 0,0 | 915 | 915 | 0 |
| Watermelon | 5 650 | 4 350 | 1 300 | 218,0 | 195,0 | 23,0 | 9 156 | 8 506 | 650 |
| Muscat melon | 560 | 560 | 0 | 16,8 | 16,8 | 0,0 | 4 805 | 4 805 | 0 |
| Cabbage | 2 520 | 1 620 | 900 | 45,4 | 34,6 | 10,8 | 3 254 | 2 554 | 700 |
| Savoy cabbage | 450 | 400 | 50 | 9,8 | 9,1 | 0,7 | 882 | 832 | 50 |
| Cauliflower + Broccoli | 760 | 760 | 0 | 12,2 | 12,2 | 0,0 | 1 830 | 1 830 | 0 |
| Carrot | 1 140 | 1 140 | 0 | 50,4 | 50,4 | 0,0 | 2 268 | 2 268 | 0 |
| Parsley | 1 680 | 840 | 840 | 46,3 | 28,0 | 18,3 | 6 019 | 4 159 | 1 860 |
| Parsnip | 130 | 100 | 30 | 4,3 | 3,9 | 0,4 | 530 | 515 | 15 |
| Celeriac | 290 | 150 | 140 | 13,5 | 9,0 | 4,5 | 540 | 355 | 185 |
| Red beet | 290 | 250 | 40 | 11,0 | 10,0 | 1,0 | 418 | 400 | 18 |
| Horseradish | 1 300 | 1 000 | 300 | 11,0 | 9,5 | 1,5 | 1 320 | 1 170 | 150 |
| Asparagus | 1 200 | 500 | 700 | 3,8 | 2,2 | 1,6 | 1 710 | 1 110 | 600 |
| Onion | 2 350 | 1 600 | 750 | 62,0 | 54,0 | 8.0 | 4 464 | 4 044 | 420 |
| Garlic | 1 200 | 600 | 600 | 7,8 | 5,3 | 2,5 | 3 120 | 2 420 | 700 |
| Cucumber for canning | 560 | 560 | 0 | 13,0 | 13,0 | 0,0 | 1 222 | 1 222 | 0 |
| Green peas | 14 890 | 12 000 | 2 890 | 78,0 | 66,4 | 11,6 | 7 500 | 6 400 | 1 100 |
| Sweet maize | 34 000 | 30 000 | 4 000 | 452,0 | 392,0 | 60,0 | 19 436 | 16 986 | 2 450 |
| Bean | 3 800 | 2 000 | 1 800 | 31,0 | 25,5 | 5,5 | 2 015 | 1 605 | 410 |
| Other vegetables | 1750 | 1 000 | 750 | 24,0 | 16,5 | 7,5 | 2 880 | 2 320 | 560 |
| **Total:** | **77 660** | **62 470** | **15 190** | **1 189** | **1 031,8** | **157,2** | **80 164** | **70 251** | **9 913** |

*Table 2. Production and regional distribution of pomiculture in 2013 (Source: www.fruitveb.hu)*

| **Plant species** | **Total area (ha)** | **Irrigated (%)** | **Non-irrigated (%)** | **Irrigated (ha)** | **Non-irrigated (ha)** | **Yield volume (1000 t) Total** | **Yield volume (1000 t) Irrigated** | **Yield volume (1000 t) Non-irrigated** | **Production value (mln HUF) Total** | **Production value (mln HUF) Irrigated** | **Production value (mln HUF) Non-irrigated** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Apple | 26 000 | 25 | 75 | 6 500 | 19 500 | 585,0 | 205,0 | 380,0 | 44 460 | 15 580 | 28 880 |
| Pear | 2 500 | 30 | 70 | 750 | 1 750 | 36,0 | 15,0 | 21,0 | 3 600 | 1 500 | 2 100 |
| Cherry | 2 700 | 25 | 75 | 675 | 2 025 | 15,0 | 6,0 | 9,0 | 4 500 | 1 800 | 2 700 |
| Sour cherry | 15 300 | 15 | 85 | 2 295 | 13 005 | 66,0 | 21,0 | 45,0 | 16 500 | 5 250 | 11 250 |
| Apricot | 4 000 | 30 | 70 | 1 200 | 2 800 | 23,0 | 12,0 | 11,0 | 5 060 | 2 640 | 2 420 |
| Peach | 4 100 | 25 | 75 | 1 025 | 3 075 | 40,0 | 16,0 | 24,0 | 6 000 | 2 400 | 3 600 |
| Plum | 7 800 | 20 | 80 | 1 560 | 6 240 | 60,0 | 20,0 | 40,0 | 3 600 | 1 200 | 2 400 |
| Strawberry | 700 | 95 | 5 | 665 | 35 | 7,5 | 7,0 | 0,5 | 4 200 | 3 920 | 280 |
| Raspberry | 400 | 50 | 50 | 200 | 200 | 1,3 | 1,0 | 0,3 | 780 | 600 | 180 |
| Bramble | 300 | 50 | 50 | 150 | 150 | 2,0 | 1,6 | 0,4 | 500 | 400 | 100 |
| Gooseberry | 150 | 30 | 70 | 45 | 105 | 1,0 | 0,5 | 0,5 | 250 | 125 | 125 |
| Currant | 1 400 | 5 | 95 | 70 | 1 330 | 7,0 | 0,5 | 6,5 | 980 | 70 | 910 |
| Walnut | 5 900 | 10 | 90 | 590 | 5 310 | 7,8 | 1,0 | 6,8 | 6 630 | 850 | 5 780 |
| Elder | 4 600 | 10 | 90 | 460 | 4 140 | 11,0 | 3,5 | 7,5 | 1 210 | 385 | 825 |
| Other fruits | 3 500 | 10 | 90 | 350 | 3 150 | 23,0 | 4,0 | 19,0 | 1 150 | 200 | 950 |
| **Total:** | **79 350** | **4** | **11** | **16 535** | **62 815** | **885,6** | **314** | **572** | **99 420** | **36 920** | **62 500** |

Sprouting can be performed in case of plants planted from seeds. In nursery gardens wither of young plants must also be prevented therefore we use freshening irrigation. In recent times the retardation of flowering has appeared cooling the plant in order to postpone the flowering and this way to avoid the frost damages of blossoms in late frosts. In order to achieve continuous assimilate production protection must be ensured against high temperatures also in other phases of the growing period.

Liquid fertilisers delivered with the irrigation water helps the acceleration of growth. Its advantage is that it infiltrates to the plant roots along with the water and it is almost fully utilized. Foliar spray fertilizers containing micronutrients can also be delivered with water. The same is true for the chemicals serving pest management.

Prior the action the colouring irrigation could be carried out when the conversion of chlorophyll into anthocyanin is achieved with the cooling effect of water. In case of grapevine the dry period before harvesting is influenced with moistening irrigation to help the formation of Botrytis cineraria promoting the development of noble rot mould on it.

We hear little about sand retention irrigation however it is applied widely in our country. The delivery of water causing cohesion could be a solution for the protection of our soils in Mezőség stirred up by windstorms. (The protection against dust-clouds owing to the shallow cultivation of recent years would be important). Frost protection irrigation belongs to the classical irrigations with special purpose. It does an advantageous service after blossoming or before crop harvesting (e.g. in case of green pepper).

We must not forget the most widespread water supplementation irrigation that can supply the water to the root zone in the temperate and subtropical zones of the world.

We can see how versatile role water and irrigation have in creating the optimal conditions of survival of plants. Its utility depends on its application in time which is based on numerous natural laws. Without being aware of their correlations the optimum cost-benefit ratio cannot be achieved. It is extremely important to find the ratio between the quantity required ecologically and the economically feasible quantity.

In terms of water resources management the coordination of the relations of water withdrawal – water conveyance – distribution – delivery is important in order to accomplish more crops per drop.

From the horticultural crops mostly the vegetables are vulnerable to weather conditions. For their supply and protection the most important tasks are to supply water continuously and to ensure the technical conditions of the delivery according to the plant's demand. According to an old saying an equal sign can be put between irrigation and vegetable production. In this light it is important to coordinate the optimum places of production and water resources as it is the expected interest of farmers and the national economy as well.

The high investment costs of closed cultivation systems also make necessary the even water and nutrient supply in order to achieve high yields. This very precise dosage can be achieved with the application of the micro/nano irrigation technology that has been spreading in East Asia (Japan, China and Thailand). In Hungary its application has not happened yet, nevertheless its basic concept was patented also in this country 25 years ago.

It is an important task to organize the utilization of the existing irrigation plants (indeed in need of reconstruction). The renewal of the establishments dismantling their pumping plants, water delivery equipment can be easier to complete than to organize the land owners for the sake of the common utilization. However, the stock exchange of Chicago does not punish or reward according to being a proud citizen of a given country but based on preparedness, diligence and efficiency. The decision makers' task is to organize it and future generation will judge their common sense.

## TERRITORIAL EXPANSION OPTIONS OF IRRIGATION

### National irrigation survey

In Hungary the Ministry of Regional Development in cooperation with the Hungarian Chamber of Agriculture conducted a national survey during the first quarter of 2014 among the agricultural producers (farmers, agricultural cooperatives, companies) on their current irrigation water use and future irrigation plans and irrigation water needs. 4000 questionnaires were returned via a newly developed web site. One of the main summaries of the national irrigation survey is presented in Table 3.

*Table 3. Main summaries of the year 2014 national irrigation survey in Hungary. ( OVF 2014)*

| | No. | Requested amount of water ($m^3$/year) | Irrigated area (ha) |
|---|---|---|---|
| Farms which have water rights permit and actively do irrigation | 1 052 | 228 685 933 | 109 226 |
| Farms which have water rights permit, but do not irrigate | 88 | 3 783 762 | 4 036 |
| Farms without water rights permit, and indicated that they would irrigate, and there is available water resources for them | 3 031 | 280 862 452 | 126 117 |
| Farms without water rights permit and indicated that they would irrigate, but there is no available water resources* | 2 740 | 119 098 966 | 91 604 |

* Note: No available water resources means that either there is no water body from which irrigation can be solved or the water body is not in good or better status according to the Water Framework Directive classification. No water rights permit can be gained for irrigation if the water body is not in good or better status.

### Expert's opinion

Three ideas were formulated as a result of discussions with long-lived Kurt Budavári hydraulics engineer with ruby degree who died in the 95$^{th}$ year of his life in March 2016 (*Budavári 2013*).

Idea 1 - One part of the Kisköre Barrage and its Irrigation System is the Irrigation System of Nagykunság having the largest capacity. The main canal built in 1968 is able to deliver a large amount of water. In itself provides opportunity to perform the direct irrigation in the connecting areas. Water supply of the areas far away from the main canal (groups of irrigated farms made up from irrigation plants) can be solved with the building of branch canals. This way only several canals must be built making possible the irrigation of almost 300 000 ha. (Its realization may become possible in case of extensive international demand for food supply for the world's population). The Main Irrigation Canal of Jászság branching from Lake Tisza – which means the water body impounded by the barrage – should be built in its whole length along with the connecting branch canals.The first 20 km section of the main canal had been built by 1968. If it was implemented it could provide irrigation for 250 000 ha.

Idea 2 - According to Vásárhelyi's proposal the construction of the Barrage of Csongrád is a part of the regulation of River Tisza. An idea for the future generation to think on is the implementation of the reservoir of Alpár through which the South Lake Tisza would be created affecting an area up to the loess ridge of Orosháza. It must be emphasized that a rich natural environment could be created similarly to Kisköre (the Lake Tisza) through a multi-purpose service system.

Idea 3 - As a result of the excellent soil conditions the Stud Farm of Mezőhegyes can be regarded as the most successful farm of the Hungarian irrigation development. In the land of 6000 hectare the seed production became reliable with the irrigation. The water supply of these areas is included also in the Treaty of Trianon. In the years with low precipitation it occurred that only the upper 60 cm became wet and with this condition the production of high-value crops would have been unrealizable. The continuous water supply is extremely important for the sake of nutrient utilization of the soils of this place. The irrigation system could be operated building upon the Transylvanian water resources in the future too. For its expansion the location of the water resource was defined in 1974 (more than 40 years ago); the mountain reservoir and the connecting main canal would be located there. The line would cross the border near Battonya. During the actual water supply 50% of the initial water resources reach the fields to be irrigated. For the sake of water savings the use of paved canals or closed conduits are recommended.

**Irrigation by Sewage Water**

Average years - in terms of precipitation - provide sufficient rainfall for agriculture in Hungary, however, in case of prolonged droughts no sufficient reserves can be found in reservoirs to meet the demands. For this reason it is highly important to explore viable opportunities beside relying on precipitations and surface waters and make use of them. There are two forms at hand. One of them is pumping out of groundwater including stratum waters. The other solution could be the use of treated sewage water.

Utilization of this method in the arid zones of the world is more and more widespread. In Israel for instance 85% of the waste water is utilized mainly for irrigation. Agricultural produce of this method totally comply with the strict British food-safety prescriptions. As for Greece and Italy, these countries also make use of about 12-16% of the sewage for useful purposes. However, in some African countries untreated wastewater is used to nourish plants.

In Hungary the idea of irrigation with waste water goes back to the beginning of the 20th century. The Royal Hungarian Experimental Institute for Limnology and Wastewater Treatment was licenced in 3rd of February 1906 by a Royal Decree proposed by Minister of Agriculture Ignácz Darányi (1849-1927) initiated by János Landgraff (1857-1930) Inspector of Fishing Industry. The first experiments were related to providing nutrient for meadows, but the results were not really used widespread. The real development started in the early 1960s. This time poplars accustomed to humidity were planted mostly in the vicinity of sewage plants. Trees cut down in age between 10 to 15 years could be well utilized. On the other hand, 25-30 year old trees with big foliage and meagre roots became victims to stormy winds. In the field of crop production the seed grain producers took advantage of the opportunity since their products did not become part of the food chain.

At present the optimal choice is growing energy plants. The flooding irrigation proved good in rice production and can be utilized also for meadow, cane and tree cultivation. By flooding irrigation method the use of renewable energy can be significantly increased, as the product can be stored even for longer period (several months). The mechanically purified sewage water used for irrigation contributes to the biomass production and it plays an important role in cutting the energy price, a policy enforced by the Government.

## RECOMMENDATION FOR SETTING UP AN IRRIGATION PROJECT OFFICE AND ITS SCOPE OF ACTIVITIES

**Controlled utilization of groundwater withdrawal.**

Reason: Actually there are about 100 thousand illegal water withdrawals. The introduction of water permits – bound to moratorium – is missing for the controlled water supply.

Consequence: Produce becomes predictable with the knowledge of the water withdrawals. A higher level of natural vegetation can be formed through groundwater recharge.

**Preservation and expansion of irrigated areas because otherwise marketable cultivation shrinks to a fraction of the actual growing.**

Reason: As a result of the climate change extreme loads occur increasingly in the growing period causing a significant decrease in the vegetable condition and in case of reoccurrence they can lead to dying-out.

Consequence: Produce is not marketable either quantitatively or in qualitatively. Market loss is guaranteed.

**Renewal of irrigation plants**

Reason: After the regime change so called rainfed cultivation was carried out in the fragmented areas. The most important units of the irrigation plants were misappropriated.

Consequence: In the possession of previous experience most farmers could carry our cultivation with reduced use of their own resources in modern circumstances. Through concentrated water supply, nutrient management and plant protection quick return of the investment can occur.

**Establishment of model farms**

Reason: In the period between World Wars I and II the owners of the so called modern chivalric (vitézi) lands produced with the help of cultivation managers with higher efficiency compared to their surroundings and they supported other farmers' knowledge growth.

Consequence: The rehabilitation of the production regions could be achieved with the knowledge gained from fellow-farmers. As a result of the organized cultivation we could hold on in foreign markets too.

**Granting assistance for the organization of associated irrigation-based cultivation**

Reason: Actually the areas of cultivation are scattered thereby organized irrigation-based cultivation cannot be performed. Quantitative and qualitative market demands can be fulfilled only through coordinated work.

Consequence: Taxation originating from the surplus yield resulting from investments contributes to the increase of national economy.

**Increase of the processing capacity**

Reason: After the change of regime the high-capacity canneries closed down.

Consequence: Products could be produced on an industrial scale meeting the international market demands and through organized buying trade relationships can be maintained on the long term.

**Increase of the cooling capacity**

Reason: In order to preserve the nutritional value of goods produced and harvested at appropriate temperature the creation of „preserving conditions" becomes necessary.

Consequence: Harvesting in state of maturity that means a product with high nutritional value for the consumer.

**Modernisation of the road network**

Reason: For the fast and safe transportation and in the absence of road conditions adequate to the weather conditions the shaking and the slow transport can result in the loss of value of the goods.

Consequence: Through semi-stable (improved structure) road structure with cambered cross-section the development of safe transportation.

**Interest representation initiative for the maintenance of community facilities as needed**

Reason: For the cost effectiveness through regular maintenance of road and sewer network the access to the production areas must be ensured.

Consequence: Development of fast transportation, drainage of the excess water from agricultural fields, maintenance of the required growing period.

**Organization of trainings at various levels**

Reason: There is no targeted academic agricultural water management professional training in Hungary.

Consequence: Near the production areas higher level vocational training (2 years), BSc and MSc training should be established. Through a prepared farmer society rational cultivation can be performed meeting international challenges too.

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# Water quality protection in Hungary - policy and status

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**Abstract**
The quality of surface and groundwater in Hungary are determined by the pollution loads from different point and diffuse sources, the hydromorphological alterations of rivers' and lakes' beds and water regime, as well as the quality of transboundary rivers entering into the country. In the last some decades relevant water protection legislation and state administration system have been set up. The responsible organizations controlling the quality of waters operate monitoring networks. On the basis of measured data the ecological and chemical status of surface waters, as well as the chemical and quantitative status of groundwater are assessed using the common principles determined by the EU Water Framework Directive (WFD). This paper gives an overview of the main water quality challenges in Hungary, briefly discusses the legal, institutional, monitoring and assessment methodological developments over the last half century. That is followed by a concise description of the current status of surface and groundwater resources in the country. It is concluded that although the quality of waters is much better today than it was in the 1970-80s, implementation of significant number of further measures is necessary to fulfil the environmental objectives required by EU WFD until 2027.

**Keywords**
Water quality protection; surface and groundwater; ecological and chemical status; point and diffuse pollution sources; chemical pollutants; water quality monitoring; water quality status assessment; programs of measures.

## INTRODUCTION

In principle surface waters and groundwater are renewable natural resources. In addition to adequate volumes of water, the social and economic development is also dependent on good water quality. The human activity is the main cause of pollution that makes water polluted, resulting in even dangerous and unusable status of water for different uses. To ensure, that all reasonable and practicable measures are taken to protect, restore and enhance the quality of the environment, including waters, such a policy is needed that supports the principle of ecologically sustainable development.

The interest of society for protection of surface and groundwater against contamination increased during the past decades in Hungary. Regulations and actions to limit pollution, manage wastewaters, protect and improve the quality of waters became gradually part of the national environmental protection and water management policy. This article intends to give a brief overview about the main pressures and impacts determining the quality of waters in Hungary, and about the legislation, relevant institutional system and measures, necessary for further improvement of quality of waters.

## THE MAIN WATER QUALITY ISSUES IN HUNGARY

More than 95 % of the Hungarian surface waters are originated from catchments located upstream of the country and a significant part of the groundwater bodies is also divided by borders. Therefore the quality of our water resources is highly dependent on the incoming water quality, and on all activities affecting the quality of incoming waters from upstream neighbouring countries.

Moreover, there are many other pollution sources within the country too, which highly influence the quality of our waters. Most of the water quality problems are caused by

- high amount of organic and nutrient (nitrogen and phosphorous components) loads,
- hazardous chemical pollutants discharged into waters,
- hydromorphological alterations affecting the ecological status of waters,
- pollutions and over-exploitations of groundwater.

These problems are considered as significant water management issues, which require appropriate measures to ensuring adequate quality of surface and groundwater everywhere in the country. The above pollutants mainly originated from

- point sources (e.g. treated wastewater discharges from treatment plants or not treated sewage discharges through sewage network; wastewaters from industrial installations),
- diffuse pollution sources (e.g. runoff entering into waters from agricultural sites and activities, from urban and other areas, from illegal or inadequate waste landfills, „historically" polluted areas; pollution loads from rainwaters, inland waters, air-pollution depositions, and from natural origin background pollution sources).

The higher concentration of organic and nutrient substances can change the living condition of aquatic ecosystems. The decomposition of the organic substances consumes the dissolved oxygen, and the high amount of nutrients can accelerate the growth or decay processes of the water related flora in unnatural degree (eutrophication, extreme growing of algae and seaweeds, decay of reed areas, densely overgrown of river channels, lake and ponds bands, etc.). Many Hungarian surface waters (especially lakes) are in eutrophic status, partly due to high amount of pollution loads and partly to the natural hydrological and hydrometeorological conditions that are typical to the country. In case of groundwater the higher nitrate concentration below settlements is mostly the consequence of the non-collected wastewaters, and the inadequate use of fertilisers and manures on agricultural areas.

The nutrient emission loads polluting surface waters originate approx. 40% from point and 60% from diffuse pollution sources in Hungary. The high amount of organic and nutrient compounds can cause deterioration of the water quality not only in the Hungarian waters, but also effect the downstream Danube sections. The total amount of these pollutants, originating from the entire (international) river basin (including Hungary) significantly contributes to the eutrophication status of the Danube Delta in Romania and to the deterioration of the water quality of the Black Sea, as well. For the estimation of the spatial patterns of nutrient pollution sources in the basin contributing to the total emissions and assessment of different pathways of the emissions into waters, the MONERIS model was applied for the entire basin using the current hydrological conditions (2009–2012) during the preparation of the international level Danube river basin management plan in 2015. *(Fig. 1. and Fig. 2.)* The total nitrogen (TN) emission load was estimated as 605.000 tons per year, and the total phosphorous (TP) as 38,500 tons per year. 5 % of the overall TN and 7 % of the TP emission originated from the Hungarian territory by the model estimation. (The whole country belongs to the Danube river basin, and shares 11.6 % of the total river basin area. Consequently the country's nutrient emission load is lower than its territorial ration.)

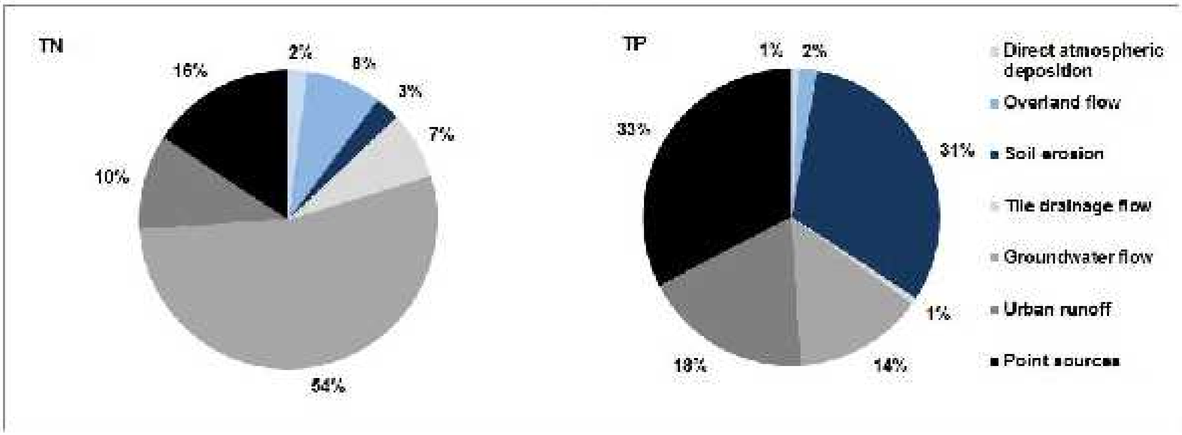


*Figure 1. Share of pathways of total nitrogen (TN) and total phosphorous (TP) emissions in the whole Danube Basin (2009-2012 reference period) (Source: ICPDR 2015)*

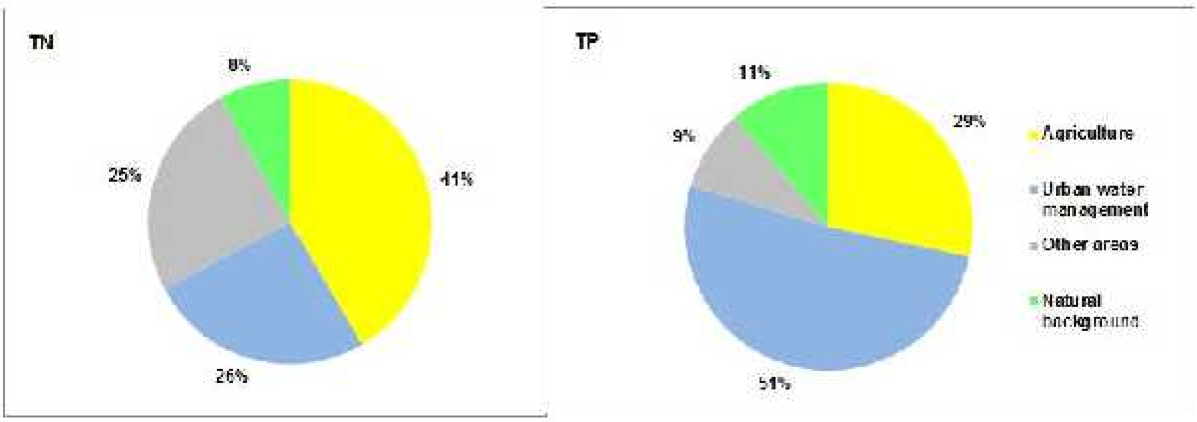


*Figure 2. Share of sources of total nitrogen (TN) and total phosphorous (TP) emissions in the whole Danube Basin (2009-2012 reference period) (Source: ICPDR 2015)*

The inadequately treated industrial wastewater can discharge different contaminants into the receiving waters, especially if the best available techniques (BAT) is not applied. Municipal wastewaters often contain different chemical pollutants also, even after treatment. Chemical pollutants can originate from different diffuse sources as well, e.g. from the excessive or improper use of agricultural chemicals. The so called „historically" polluted sites cause local quality problem, mainly in the case when the remediation measures are not in place or not effective enough. These chemicals can endanger the water ecosystems, and can be harmful for human health as well. In some parts of Hungary (mainly in the Tisza River Basin) the higher level of geological background contamination of the soil and rocks can pollute the waters as well, primarily with different types of heavy metals. In these cases concentration of some quality parameters in the groundwaters can exceed the drinking water limit values and the water can be used only for drinking water supply after adequate treatment. The accidental (havaria) pollution cases coming from upstream catchments areas are also frequently associated with dangerous substances pollutions.

The hydromorphological alterations, which modify the natural water beds, the water balance, the runoff conditions of the rivers and lakes can significantly affect the living condition of the aquatic ecosystems and the quality status of waters. Most of the Hungarian waters are affected by previous interventions, which significantly changed their hydrological and morphological conditions. Most of the problem are caused by the limitation of migration of aquatic organisms, generally fishes, along longitudinal and cross directions, because of the regulation of rivers and building flood protection facilities. The management of inland waters and the increasing frequency of drought periods can cause significant changes in the water regime of rivers and lakes, and significantly impact the quality status of wetlands and water ecosystems.

The groundwater abstractions represent significant volume in Hungary, and approx. 80% of the abstracted waters serves drinking water purposes (as more than 95% of the drinking water supply is based on groundwater). The excessive water abstraction can cause decreasing groundwater level in some parts of Hungary (mainly on the East part of the country, in the region between the Danube and Tisza Rivers). As a consequence of excessive groundwater abstraction agricultural losses, drying or degradation of wetlands may occur. Additionally, there is high number of illegal ground water wells without any permits, which situation might threat not even the quantity, but also the quality of groundwater resources. The shallow (near-surface) aquifers are mainly exposed to anthropogenic pollution coming from the surface. The natural recovery of contaminated groundwater is very slow. It takes several decades, depending on the substance. As contamination remains often hidden for a long time, it can spread in groundwater unobserved. Remediation of polluted groundwater is very expensive and for some contaminants not effective. The country is rich in thermal waters, but from this point of view it is also true, that overusing or incorrect use of these resources can lead to decreasing pressure and temperature of thermal waters layers.

## WATER PROTECTION LEGISLATION IN HUNGARY

In 1952, some years after the World War II, a legislation entered into force containing, the first time, water protection aspects (2/1952 MT decree). It prescript the rule, that wastewaters could be discharged into water recipients only after treatment. Some years later it became a legally binding obligation that installations and plants, discharging wastewaters into surface waters, could be established only with treatment equipment. The existing plants had to be supplied with treatment facilities additionally by 1971. In 1961 the wastewater fine system was introduced into the legislation. The operators of the plants had to pay pollution fines and wastewater discharge fees. The concentration of pollutants discharged into waters was measured by the water authority laboratories. This regulation was modern, at that time, despite the fact that it did not prevent pollution of waters above the limit values.

In 1964 the IV. "Water Act” was adopted, and after it lower level regulations entered into force as well, which reinterpreted and modernized the concept of wastewater fines. More than 30 different pollutants and harmful compounds were put on the fine list, and later the progressive fine system was introduced into the regulation also. Emission limit values were determined by law, and as a consequence of the new system the possibility of the over pollution of recipient waters decreased. Altogether, as the effect of the measures (including pollution fines) implemented in 1960-70s years the speed of the pollution degradation of surface waters slowed down a bit, but not enough, so introduction of newer rules became necessary for further protection. For this reason, at the end of the 1970s the priority water quality protection areas, which were extremely sensitive for pollution, were designated by law. On these areas stricter emission limit values and higher fine items were determined. The water protection plan system was also introduced as a tool for authorities to encourage operators with lower progressive fines to plan and implement advanced water protection measures and further technological developments.

These regulation principles were further developed when new legislations concerning the wastewater and sewage canal fines were issued in 1984 (3/1984 and 4/1984 OVH Decrees). The list of priority protected areas was extended by new areas, e.g. for the protection of groundwater aquifers; setting of fees became possible in case of accidental pollution of groundwater also; the emission limit values of harmful compounds were restricted. The water authorities got further power to prescribe more stringent, so called individual limit values for operators taking into account the water quality status of the recipients and applying more stringent sanctions against operators causing accidental (havaria) pollution cases.

From groundwater aspects, in the second part of the 19th century the interest of the society for protection against contamination became more intensive from the point of view of water uses. It became important to establish only wells, through which the contamination from the surface could not get down to the aquifers, and ensure that there were no pollution sources and polluting activities in the surroundings of the springs and wells, used for drinking water supply or as mineral and medical waters. In 1952, the general water licensing processes were re-regulated. In frame of this legal process the permitting procedure of establishment of public drinking water supply wells and wells for mineral and medicinal water extraction purposes were introduced. Legally binding technical regulations (national standards) were also adopted, containing technical details of wells construction and operation, ensuring additional protection of groundwater quality. In 1960 the obligation of preparation of hydrogeological expert opinion, hydrological log and cadastre of drilled wells became part of the regulation. The other legal tools, serving protection of water resources used for drinking water abstraction, were the designation of protected areas. The different types of land uses were restricted or prohibited on these areas. This regulation was also further developed to ensure higher level protection of groundwater resources beyond public water supply uses. But the legislation contained only a very general prohibition against the harmful pollution of other groundwater, without correct definition of the pollution cases.

In 1995, new acts entered into force on the field of water management and environmental protection, and on their basis the lower level legislation was updated, as well. The „Environmental Protection Act" (53/1995 Act) laid down the basic principles of protection of all environmental elements on the basis of applying uniformly based environmental quality objectives, and the „polluter pay", „prevention of pollution", „principle of precautions", „environmental liability" and "cost recovery" principles. It strengthened the protection of the designated areas. For all environmental elements (water, air, soil, etc.) the same permitting and controlling principles were introduced into legislation. The definitions of immission and emission limit values, and the responsibilities and duties of the different actors in the environmental protection processes were also defined by the act. The principles of the „Water Management Law" (57/1995 Act) established the further development of the lower level legislation relating to the different water uses, to the permitting system, to determine the tasks and responsibilities relating to water supply and wastewater collection and treatment, flood and inland water protection. The Act ensured special protection for drinking water sources, and one of its later modification introduced the river basin management planning process into the water management practice.

In 1997 new governmental decree (No. 123/1997) came into force on special protection of groundwater resources used for exploited or designated drinking water sources. The decree prescribed the rules of designation of protection zones on the designated drinking water source areas. Protection again pollution of other groundwater aquifers (lying outside of these protected areas, and covering approx. 95% of the country territory) became possible on the basis of the environmental act. Based on it, the general rules for the protection of groundwater against contaminations were set up in a new Governmental Decree (No. 33/2000) and the detailed legislation in ministerial decrees in 2000. The regulation covered the protection of soil, as one of the environmental elements, too. The decree introduced the obligation of detailed investigation in case of earlier polluted areas to ensure, that the appropriate remedial measures can be determined. In addition, since early 2000s, water conservation requirements of groundwater have also been gradually included into legislation of other sectors (e.g. waste management, industrial, agricultural, mining regulations). This made it possible that the whole regulation could gradually cover all kind of activities, associated with point and diffuse pollution sources.

Hungary joined the European Union on 1 May 2004. One of the preconditions of the accession on the field of environmental protection was the transposition of the whole community legislation ("acquis communautaire") into the Hungarian law. Despite the fact, that the national environmental legislation that time was quite modern in Hungary, and many of its elements were already transparent with the EU regulation, during the 2000-2004 period huge amount of further legislation and capacity building activities had to be taken for the total transposition, even on the field of water protection. More, than 20 modified or new legislation entered into force on the water management field, which established further improvement of the quality of water resources in Hungary.

New environmental quality standards were introduced relating to the chemical quality of waters, including those priority substances, which were especially harmful to aquatic ecosystems and to human health. Relating to the quality of drinking waters, bathing waters and further requirements of different types of protected areas new limit values were determined also in the national law, based on the EU prescriptions. National action programs started on the field of urban (communal) wastewater collection and treatment, on the proper handling of wastewater sludge. For decreasing the nitrogen and pesticide pollutions from agricultural activities, relevant legislation was set up also. The authority control system was strengthened by introduction of the integrated pollution prevention control (IPPC) principle, taking into account the protection of all environmental elements in one permitting procedure. It accelerated the process, that larger industrial installations, wastewater treatment plants, waste landfills, etc., emitting higher amount of pollution into the environment, should meet the expectations of pollution prevention principle. The introduction of this legislation helped to replay the earlier typical "end of pipe" approach with applying more efficient approach of prevention in practice.

In the development process of water quality protection legislation in Hungary, one of the most significant steps was the transposition of the common EU water policy strategy into the national legislation. The 2000/60/EC Water Framework Directive (WFD) was adopted in July 2000. The WFD introduced a comprehensive and coherent regulatory scheme in practice, envisaged sustainable water policy and management, requiring co-operation and coordination on water management issues among countries, sharing common international river basins. This complex regulation integrated the protection of surface waters and groundwater, the natural and artificial water bodies, handling both qualitative and quantitative aspects. The environmental objective of the framework directive is to reach and ensure the "good ecological" and "good chemical" status of surface waters, and the "good chemical" and "good quantitative" status of groundwater by 2015, but not later than 2027. To achieve these goals an integrated approach is required, involving all relevant sectors, harmonising planning and implementation of program of measures. The effective participation of the public and stakeholders in these processes also one of the new elements of the legislation. Transposition of the WFD into the national legislation entailed updating the previous water protection legislation. The rules of river basin management planning process were transposed into the national legislation with a new Governmental Decree (No. 221/2004).

In summary, today rules for surface water protection are prescribed by the Governmental Decree No. 220/2004 and groundwater protection by the Governmental Decree No. 219/2004. The legislation is based on the general rules of the environmental and water management acts.

For all water related activities permits are necessary, which are valid only for specified period of time, generally for five years, and then have to be revised. The legislation details are prescribed in ministerial decrees, covering e.g. the immission and emission limit values, the rules of application them in official practice, the water quality monitoring, obligations of operators and authorities. By the regulation, the operators have to control their emission loads in frame of self-control system, and regularly send data and other relevant information to the authorities. The immission and emission data are stored and assessed in the National Environmental Information System ("OKIR"). The information relating to emission loads of the biggest dischargers is also available by the national and European Pollution Release and Transfer Register ("PRTR") databases, through internet.

The permitting procedure of the surface waters are based on the so called „combined principle". Firstly, the WFD compliant environmental objectives of receiving water bodies have to be taken into consideration in the permitting procedure of the new installations, or when the earlier issued permits are revised. On the other hand, the technological emission limit values, based on the best available techniques, have to be applied also to limit the emission loads. Pollution fees on the basis of exceedances of emission limit values is still also in effect, but it does not mean, that paying fees allow further extra pollution. In these cases, operators' obligation is to prepare a pollution reduction plan, approved by the water protection authority, and implement its measures by the agreed deadlines. As the worst case, the authority has the power to oblige the operators to stop the polluting activity.

The regulatory package for the protection of groundwater aims to achieving and preserving the good status of groundwater by regulation of interventions. It covers the protection of groundwater and soil, the prohibition of direct and restriction for indirect discharges of different pollutants into groundwater, the rules of preventive and remedial interventions and pollution fee system. Rules of assessment of naturally occurring substances, the quality and quantity status of groundwater, of designing and operating monitoring networks, data collection and information systems were set up by legislation also.

Upgrading the water protection legislation of course is not a finished process. From one side, it has to be continued to meet the constantly evolving requirements of the "acquis communautaire". Hungary, as one of the Member States, actively participate in the EU level legislative work, and after new or modified legislation coming into force, has to transpose them into the national legislation. Additionally, the national legislation should be updated as well from time to time. As an example e.g. on the basis of the results of river basin management plans, to ensure the implementation of program of measures from legislation side.

## INSTITUTIONAL SYSTEM

The water management regulatory and administrative organisational system has long history in Hungary. The earlier established regional water directorates (12) started to deal with water protection activities after the first relevant legislations came into force, in the 1950-60s. Special water quality protection departments have been created and water quality laboratories were also set up in each directorate. The second-degree authority tasks and the supervision of the activities of regional directorates belonged to the National Water Authority at that time.

From the end of 1980s to the present, regional organisations dealing with water quality protection tasks, were several times reorganised, following mainly the changes of ministerial level responsibilities on environmental and water management fields. In 1987 the government merged the chief offices of water management and environmental protection into one organisation, and next year, raised that organisation to ministerial level, establishing the Ministry of Environment and Water Management. The two sectors' regional authorities were also merged creating the regional environmental and water inspectorates. But in 1990 after the parliamentary election, the water management and environmental protection responsibilities were again separated into two ministries and the regional level inspectorates were also divided. The water quality protection tasks and also operation of the laboratory network remained in frame of the environmental inspectorates, under the supervision of environmental minister. The general water management duties of state, the water utility tasks, including investment programs, the flood and inland water management, and all other responsibilities, based on the Water Management Act, became the tasks of the minister, responsible for water management. The regional water directorates, responsible for operative water management, got the right to issue water management permits and act as general regional water management authorities. The environmental inspectorates were involved into the water management licensing as co-authorities.

In 2002, in the new governmental structure, the environmental and water management tasks were given to the same ministry again (Ministry of Environment and Water). On regional level the so called „green authorities" (12 regional environmental, nature protection and water protection inspectorates) were established in 2005. Practically this system remained unchanged till 2012, when firstly the flood and inland management tasks, and from 2014 also the other water related tasks (river basin management planning and water quality protection) were given to the Ministry of Interior, and the regional authority tasks were shared on this new structure also.

Currently the organisational structure, relating to water management and water protection tasks, is the following:

- The minister of interior is responsible for general water management (related to the Water Management Act), water quality protection (related to the Environmental Act) and coordination of water directorates.
- The water quality protection and water management authority tasks belong to the 12 county level disaster management directorates, and the second-level

tasks to the National Directorate General for Disaster Management.

- The operative water management tasks are the responsibilities of the 12 regional water directorates, under the co-ordination of General Directorate of Water Management. These organisations are responsible for river basin management planning and for the operation of water quantity monitoring network also.
- The analytical measurements and samplings of the state-responsibility water quality monitoring remained the task of the environmental inspectorates' laboratory network (12 inspectorates with 7 laboratories). The inspectorates belong to the county level Governmental Offices, supervised by the Prime Ministers' Office.
- Some special water related tasks belong to other ministries. E.g. soil protection, the environmental remediation programs of polluted sites, the environmental impact assessments, the IPPC permitting procedure and operation of National Environmental Information Network ("OKIR") are under the responsibilities of Ministry of Agriculture, as responsible for general environmental protection issues. Control of the quality of drinking water (tap water) and activities relating to bathing water quality are the tasks of authorities and organisations responsible for public health (also as part of county level Governmental Offices), under the supervision of the Ministry of Human Resources. Since 2014, there are new actors in the water sector: water utility managements are coordinated by the Ministry of National Development, while the financial regulation lies with the Hungarian Energy and Public Utility Regulation Office.

The water sector earlier had a research institute, called the Water Resources Research Institute (VITUKI), as a background organisation. VITUKI played a major role in the establishment and development of water protection institutional framework and in solving other sort of state-responsibility tasks. After 60 years of operation the institute was closed down in 2014 leaving serious professional gap behind. The other former background agency, the Environmental Management Institute (KGI) was also closed app. 10 years ago. This institute was earlier responsible for the collection of surface water quality monitoring data, status assessment, coordination of remediation, and other types of tasks. Some special tasks, mainly relating to monitoring and assessment of groundwater resources, and well documentation management are implemented by the Geological and Geophysical Institute of Hungary (and its predecessors).

Though there are e.g. special expert groups (e.g. biologists, ecologists, water quality and water management experts, economists) working in institutes of the Hungarian Academy of Sciences and on university faculties (e.g. Budapest University of Technology and Economics), who are participating in special water relating research programmes, but this is always dependent of the available financial sources. At this moment there is a plan that within the Hungarian Academy of Science institutional structure a new water research unit would be established.

## WATER QUALITY MONITORING SYSTEM

One of the most important tools for the protection of the quality of waters is the regular investigation (monitoring) of the water status by sampling and analytical measurements. On the basis of the assessment of the monitoring data the right water protection measures can be designed, and the effectiveness of their implementation can be measured. The history of the hydrological monitoring (measuring water quantity) date back for centuries in Hungary. The „simple" control of water quality, e.g. for drinking water or bathing uses, has historical background as well. Sporadic records relating to the status of water quality, flora and fauna also indicate that in accordance with the technical possibilities and knowledge of the past, „water quality monitoring" started long time ago in Hungary.

Nowadays this activity is based on the environmental protection act, which states that establishing and operating measuring and monitoring systems on the status of the environment is the duty of the State. (In frame of it, the minister of interior is responsible now for the co-ordination and supervision of water quality monitoring activities.) The same act also determines that the users of the environment, the operators are responsible for controlling their pollution loads if discharging into the environment (including direct or indirect wastewater effluents), and should provide regular data to the authorities. All of this information has to be collected and stored in the National Environmental Information System (OKIR).

### Surface waters

The first published measurement data stem from 1873, when the water quality of the River Danube was discussed in terms of the cations and anions found in the river water. Only few publications are known from the first decades of the 20$^{th}$ century. The need of the society for investigating the quality of waters occurred first upon the extensive industrialization after World War II. The VITUKI made plans for the establishment of a nationwide water quality monitoring system in 1952. (The investigations covered 1400 stations of 130 rivers and 25 water quality parameters, the frequency of samplings was once a year.) Development of the laboratory network of the district water directorates started in 1956 on the basis of the professional knowledge, which was available in VITUKI. With involvement of these laboratories in the early times, large number of stations (app. 800) with low sampling frequency (app. 4 samples/year) were monitored in 1960s.

New sampling rules have been put into force in 1968. In this new network the number of stations was reduced to about 300 and the sampling frequency increased to 12 annually as the minimum. This system was considered as the establishment of regular national water quality monitoring network. (The monitoring covered the 113 most important water courses of the country, the analysis of app. 50 water quality parameters and sampling frequencies of 12, 26 and 52 per year). The national network was operated in the above described manner between 1968 and 1984. New monitoring rules were established in 1985 again. This included 250 stations and the sampling frequency remained the same.

Between 1994 and 2006 the MSZ 12749 national standard method contained the rules of the surface water quality network and the water quality status assessment principles. (The monitoring covered 109 rivers and the largest lakes, 240 sampling sites with 26 sample/year frequency.) 30-40 type of quality parameters (physical-chemical, biological, microbiological, heavy metals, etc.) were determined from app. 6000 samples, each year. The sampling and analytical works that time were implemented by the laboratory network of environmental inspectorates (established on the basis of the laboratories of former 12 water directorates). Some special parameters were measured by VITUKI and by the laboratories of public health authorities (e.g. microbiological parameters).

According to EU Member States' obligation, based on the earlier monitoring system, a new monitoring network had been established according to the requirements of the WFD and started the operation on 1st of January 2007. The basic principle of monitoring and status assessment, as well as details of operation and professional requirements are prescribed by the 31/2004 KvVM ministerial decree. The new network was set up to serve the three-level monitoring programs (the surveillance, operative and investigative sub-programmes), which serve different purposes. The frequency of the samplings fulfils the WFD requirements and varies by subprograms and the type of the quality parameters (from 1-12 times/year to 1-12 times/6 years). The analysis covers all quality elements, prescribed in the WFD. The investigation of five biological elements types (phytoplankton, benthic diatoms, macrophytes, macrozoobenthon and fish fauna) provides identification of ecological status of the water bodies. Parameters supporting biological elements, the relevant physical-chemical parameters (e.g. organic compounds, nutrients, salinity, acidification, river basin specific pollutants) and hydromorphological elements are measured regularly, as well. The WFD attaches great importance to the special, anthropogenic origin chemical pollutants, approx. 45 priority substances have to be monitored regularly. Compared to surveillance monitoring the sampling frequency in the operative subprograms is lower, generally only 4 times a year, and only the indicative parameters are measured regularly.

Nowadays, the quality of surface waters are checked in this system for all parameters with monthly frequency on 118 river and on 26 lake sampling sites, in the frame of 2 surveillance subprograms, and with lower frequency on 1134 sampling sites in the frame of 8 operative monitoring subprograms. In special cases (e.g. accidental water pollution events) investigative monitoring sampling programs are carried out focusing on problematic parameters. The monitoring is financed from the state budget and operated by the environmental authorities' laboratory network (7 accredited labs), under the supervision of the minister of interior. The hydrological (quantity) monitoring are operated by the regional water directorates, ensuring data relating to water flow, water level and morphology, necessary for the ecological status assessment.

Additionally, to these WFD monitoring programs there are other special monitoring subprograms in operation on the designated protected areas (e.g. bathing waters, drinking water sources, nitrate sensitive areas) and on surface waters with special importance (e.g. Upper-Danube section, Lake Balaton). In these programs other sectors are also participating (e.g. public health laboratories in bathing water monitoring).

On the transboundary rivers common monitoring programs are implemented with the neighbouring countries, on the basis of the bilateral water agreements. Under the umbrella of the Danube River Protection Convention the Transnational Monitoring Network (TNMN) is in operation with co-operation of the Danube countries (14 countries). 114 sampling sites on the Danube and on the main tributaries were selected from the existing national monitoring networks. There are 15 sites in Hungary *(Fig. 3)*. The sampling and the analytical methods are harmonised, and the laboratories are participating in a common intercalibration process, ensuring that the data from different laboratories are comparable. The assessment of data and their publication is done yearly. Additionally, in each sixth years, the Joint Danube Survey (JDS) program is organised in the frame of International Commission for the Protection of Danube River (ICPDR), when from the source (Black Forest in Germany) to the mouth (at the Black Sea in Romania) of the Danube River common sampling and common analysis works are implemented. Last time the JDS3 was implemented in 2013 with an international expert team working on a ship-laboratory.

**Groundwater**

The quality of groundwater is known partly from the regular control of the wells used for drinking water abstraction, and partly from the wells, established and used for monitoring purposes. Regular observations started around 1930 in the Danube-Tisza region, and from 1950 groundwater level observations covered the entire country. Observation of springs also started around 1950, together with karstic water level observations. Organization of the observation of deep groundwater and thermal waters was the task of the following decades. The more detailed, regular monitoring was further developed in 1970-80s with co-operation of different sectors and organisations. In the years before the EU accession the rules of monitoring was determined by the MSZ-10-433/1984 national standard. Additionally, from 2004 general water users who abstracted more than 100 $m^3$/day and waterworks which abstracted more than 10 $m^3$/day had to provide data about the quantity and quality of the abstracted water.

On the basis of this system a new monitoring network had been established according to the requirements of WFD and the operation started on 1 January 2007, when the new surface water monitoring network started, as well. The groundwater monitoring is operated partly by the State and partly by the users. The basic principles of quality monitoring and details of operation are prescribed by the 30/2004 KvVM ministerial decree. The quantitative monitoring rules are laid down in the 45/2014 BM ministerial decree. The WFD compliant network is composed of two subsystems. The first one is the regional (surveillance) monitoring operated by State and local government organizations. This subprogram monitors the quantitative status of groundwater observing the long-term changes of the qualitative status, caused by natural factors and human diffuse impacts (non-point pollution sources). Other part is the environmental use monitoring, which is composed of measurements and observations implemented by the users of environment, observing the impact of point sources (e.g. waste disposals, industrial installations).

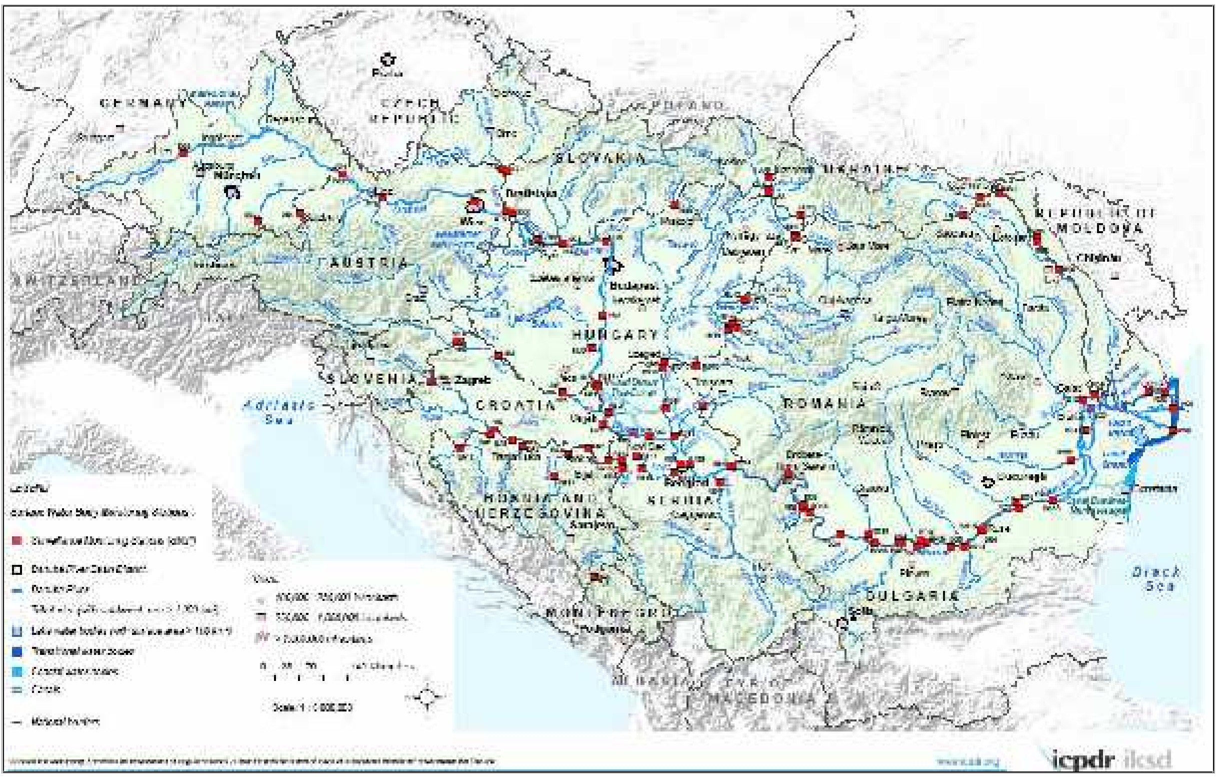


*Figure 3. Danube Transnational Monitoring Network (TNMN) sampling sites (ICPDR TNMN Yearbook, 2014)*

In accordance with WFD, the monitoring network was set up on two-level subprograms (surveillance and operative). For the assessment of groundwater status 6 surveillance subprograms are in operation in Hungary, from which 2 deals with quantitative and 4 deals with chemical status parameters. The quantitative measurements cover the water level and water load observations. The qualitative parameters measured are the general physical-chemical components prescribed by WFD, but in some chemical subprograms special pollutants, like organic solvents, hydrocarbons, other specific carcinogenic compounds (e.g. benzene, vinyl chloride), heavy metals are also analysed. The frequency of the sampling is generally 1-2 per year. The operative monitoring consists of 4 subprograms, aiming the investigation of more specific problem. Regular sampling and analysis of groundwater take place from about 1750 wells.

## METODOLOGY OF ASSESSMENT OF WATER QUALITY STATUS

The water quality status assessments on the basis of the monitoring results have to be based on comparable, purpose-designed evaluation systems. In the last decades not only the principles of water quality monitoring networks improved a lot, but similarly the methodologies of assessment of the water status.

### Surface water

In the 1960-70s the quality assessment took into account the sort of water uses (e.g. drinking water, irrigation water), and were based on national and international standards and on technical guidelines. In 1983 three-class assessment system was introduced by the MSZ-10-172 national standard method. It was replaced by the MSZ 12749 national standard assessment method in 1994. The new standard took already into consideration the ecological aspects as principle, but only on very basic level. The measured parameters were divided into 5 groups (oxygen-household, nutrients, microbiological-, micro pollutant- and „other" components). Each parameter group was assessed in 5 quality class system (excellent, good, acceptable, bad and very bad) using the yearly occurred worst concentrations for assessment. The same limit values were valid for all types of waters. Each year the assessment and a map about the quality of water were prepared and published *(Fig. 4).*

Today the data of the WFD compatible surface water monitoring has to be assessed on the basis of uniform, comparable principles in the EU countries. The status assessment mainly focuses on ecological aspects, therefore the so called type-specific qualification system was created in Hungary in last years. 10 river and 8 lake types were determined. Ministerial degrees contain the main principles of qualification, the relevant environmental quality standards and the characteristics of types. Further details of methodologies can be found in the river basin management plans documentation. The ecological and chemical status of surface waters are determined during status assessment by the principle of WFD and on their basis the so called integrated status is assessed *(Fig.5).* The „one out –all out" principle has to be applied, so the integrated water status is determined by the worse. The classification of the ecological status is determined in form of „ecological quality ratio" (EQR), by 5-grade scale (high, good, moderate, poor, bad). The actual status has to be compared to the type-specific reference condition, which means, the influences are regarded as quasi-free from anthropogenic pollution. (In case of artificial and heavily modified natural water bodies the basis of the assessment is the „good ecological potential", which means the best available water quality, besides maintaining the functions of water body.) During the assessment of ecological status not only the biological elements (phytoplankton, phytobenthos, macrophytes, macrozoobenthos and fish fauna), but all other parameters supporting the biological elements have to be taken into consideration. For the qualification of biological, physical-chemical and hydro-morphological parameters environmental quality standards were set up on national level, for each type or for groups of types of waters. The status assessment is based on the annual average data.

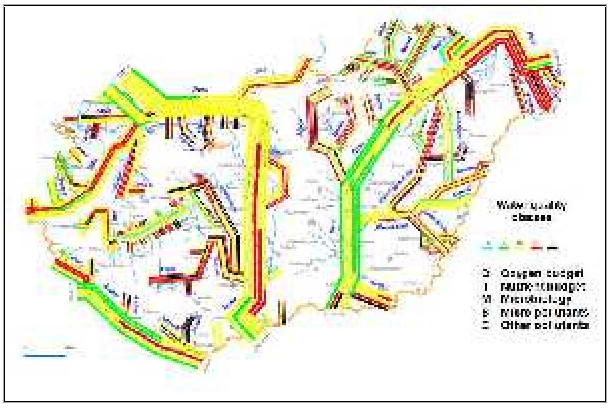

*Figure 4. Surface water quality in 2003 (Source: Ministry of Environmental Protection and Water 2005)*

The chemical status of surface waters is determined by the occurrence of harmful chemical substances in the aquatic environment. The status assessment is based on the environmental quality standard (EQS) of priority substances (45), determined on EU level by the 2008/105/EC directive. The limit values were transposed into Hungarian legislation. The qualification system is a 2-grade scale, where the quality is „good", if the limit values are not exceeded, or „failing to achieve good"(not good) when the limit is exceeded. The results of status classification are illustrated also on maps.

**Groundwater**

After 1984 the status assessment of groundwater was based on a three-class methodology, determined by the relevant Hungarian standard method. The assessment system took into consideration the uses of waters.

In the frame of the current, WFD compatible monitoring practice the status assessment of groundwater have to be implemented by the rules of the 30/2004 KvVM ministerial decree. Altogether 185 groundwater bodies were designated, which were grouped into 7 types. For the qualification, the natural background values (referring to the concentration of substances of natural origin) have to be also determined. The groundwater is in good chemical status in case if the pollutants' (occurring in the surrounding also naturally) concentrations are near to the background values, and the synthetic components with anthropogenic origin are near to zero, so not reach the limit values.

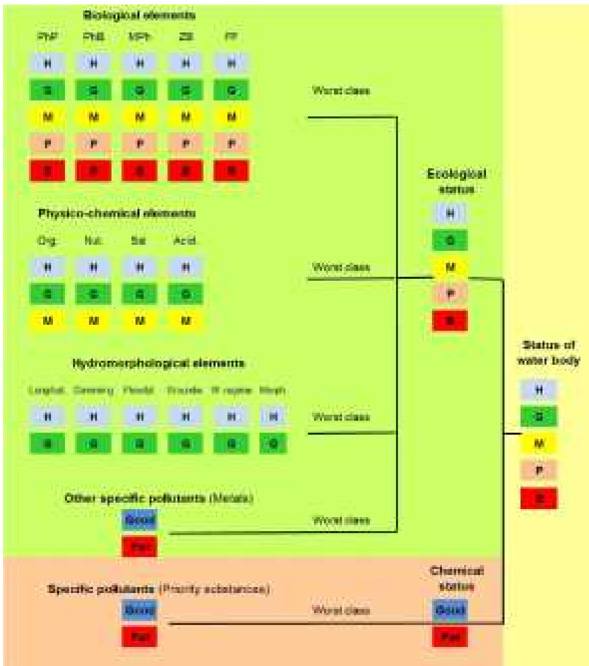


*Figure 5. Methodology of surface water status assessment by WFD (VGT1 2009)*

The quantitative and the chemical status are checked by different types of tests. If at least one of the tests shows, that the water body is „poor", the total water body status will be „poor" as well, and measures are necessary to improve the quality status to reach the „good" status again. When the status is on the limit of the „good" and „poor", or negative trend can be observed in the long term quality changes, or because of the weaknesses of methodologies the status assessment is not sure enough, the water body status is „good, but at risk", which needs further measures.

The chemical status classification is based on detection of pollution in the monitoring wells, exceeding the threshold values. The threshold value is the concentration of a pollutant, in which case there is a risk of hazardous level pollution of the so called receptors (e.g. human being through drinking water and food chain, aquatic and terrestrial ecosystems) or to different water uses. In Hungary threshold values were set up on water body, on group of water bodies and on national level for nitrate, ammonium, conductivity, chloride, sulphate, cadmium, lead, mercury, pesticides, tri- and tetrachloride – ethylene, TOC and AOX parameters.

Those water bodies are in risk, in relation to maintaining the good status, in which one or more pollutants' average concentration are gradually increasing or - in case of thermal waters - the temperature are decreasing. The purpose of the trend analyses is to indicate problems, which can occur in the actually good status water bodies in the future or significant and durable concentration or temperature changes can be already detected.

Additionally to the above methods for surface and groundwater status assessments, on protected areas, designated by law (e.g. as bathing waters, drinking water resources, designated nutrient and nitrate sensitive areas, nature conservation areas), the status assessment is implemented regularly on the basis of the special requirements and limit values of the protection purposes, also.

## STATUS OF WATER QUALITY

### Surface water

The quality of the Hungarian surface waters, mainly of the rivers, became polluted quickly from the end of 1950s. The main reason of it was that untreated communal wastewaters were entered into the fresh waters in large quantity practically without any treatment or after only minimum level of treatment. The large heavy and chemical industries with outdated technical level, not taking into consideration the environmental aspects, additionally contributed to the severe degradation of the water related ecosystems. In some smaller rivers the natural flora and fauna were practically devastated. Some larger rivers, where on their basins larger heavy industrial plants operated (e.g. Tisza, Sajó, Bodrog, Szamos, Körösök) became heavily polluted around 1960-70s. The large scale agricultural farms used fertilizers and pesticides in huge quantity. (Some of these persistent chemicals now are abandoned, because of toxic active ingredients, but sometimes still can be detected also in surface and groundwater waters.) The accidental pollution events (havaria) were also very frequent that time, mainly arising from abroad.

The population started to grow quickly in towns at the same time. The municipal wastewaters polluted heavily the surface water recipients even there where the municipal sewage network had been already built out, but without appropriate treatment plants. Budapest was a good example, where the wastewater of 2 million inhabitants was treated only approx. 30% portion in the 1980s and near to 1 million $m^3$ untreated wastewater polluted the Danube daily. (The central wastewater treatment plant started its operation only in 2010, and thus all collected wastewaters of the capital became treated.)

The lakes' quality was not much better. The quality of large lakes became worse in 1950-60s, first of all the Lake Balaton, where in spite of the growing number of tourists, only minimal level wastewater infrastructures were built at that time. The lake became hypertrophic, during summers caused by mainly cyanobacteria (blue-green algae). Mass production of cyanobacteria species were frequent, which were harmful to human health. Fish kills were also quite a frequent problem, mainly because of the high organic and nutrient pollution level, but partly because different types of non-native fish-species were settling into the lake.

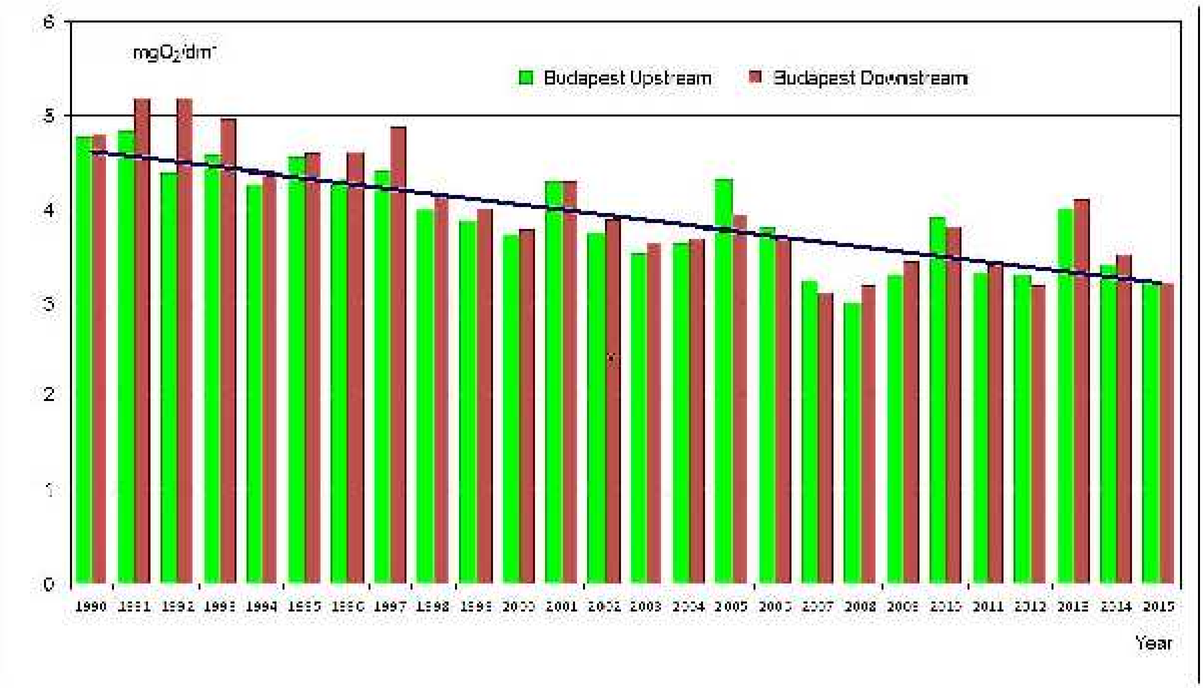


*Figure 6. Changes of organic pollution level in the Danube in Budapest. (Yearly average concentration of $COD_p$ - Chemical Oxygen Demand with permanganate (Source: OKIR 2016)*

As a positive effect of the water protection legislation entered in force in 1960-80s the earlier rising pollution trends started to decrease a bit. But only the last decade of the 20th century brought more significant improvements in the quality status of the Hungarian waters *(Fig. 6)*. In 1988-1990 the big political changes were followed by substantial economic recession in Hungary and in the neighbouring countries. It was the time also, when in other upstream countries (Germany, Austria) sewage treatment plants with higher level of treatment were intensively built. Both facts resulted in substantial decrease of pollution loads entering into surface waters. For illustration a single numerical data can be mentioned here: in 1994 the total of nitrogen fertilizer application rate was as low in Hungary as in 1960s, and it was about one-third of the maximum rate of 1988. At the beginning of the 2000s, some of the quality parameters started to show slightly increasing trends again, as the industrial and agricultural activities started to recover again, but because using generally higher level technologies than earlier, it caused relatively lower level pollution of surface waters. Additionally, in this period, investment programs in wastewater collection and treatment became more intensive. The quality of most of the Hungarian surface waters belonged to the middle, „acceptable” class according to the 5-class assessment system mentioned earlier around early 2000s and approx. 15-20 % of surface waters reached the limit values of the good quality by the same assessment method.

The ecological and chemical quality assessment of the WFD compatible data was implemented for the first time during the preparation of the first national river basin management plan (RBMP1) published on 22nd December 2009. The plan was revised in 2015 (RBMP2), and during this process the status of river water bodies was reassessed, as well. For RBMP2 the data from the period 2008-2012 were used. On the basis of ecological status 9% of the total designated river and lakes water bodies (1078) is in “high” or in “good” quality, but three-quarter of the water bodies required further measures to reach the good quality *(Fig. 7).*

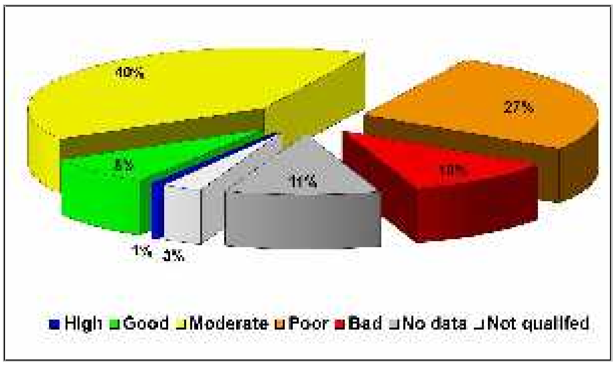


*Figure 7. Ecological quality of surface waters in ratio of total water bodies (VGT2 2015.)*

The ecological status is determined mainly by the status of biological elements. From the parameters, supporting the biological elements, the classification of the physical-chemical elements shows generally a better picture, namely 59% of the assessed river water bodies and 44 % of the lake water bodies are in “good” or “high” quality *(Figures 8 and 9).* From the parameter subgroups the nutrient- and oxygen-households (organic) compounds are in the worst status, which certify that the eutrophication is a significant problem in the Hungarian waters still today due to anthropogenic pollution and also to natural conditions. One third of the surface water bodies are in eutrophic status. Although most of the lakes are not eutrophic, but one third of them are potentially eutrophic despite the fact, that the nutrient pollution loads have been significantly decreased during the last decades as a result of different measures.

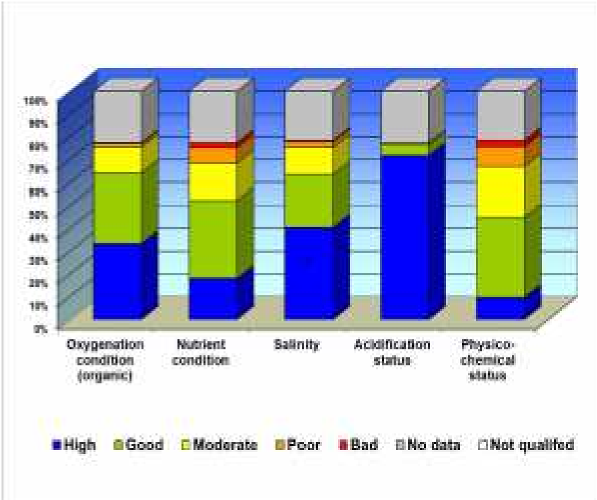


*Figure 8. Status of physical-chemical parameters of surface waters (VGT2 2015)*

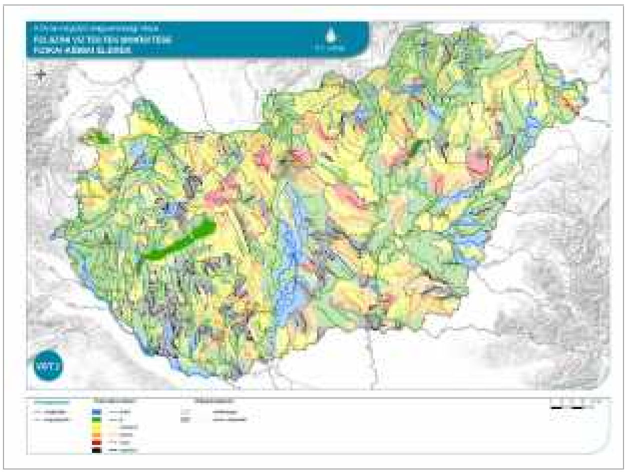

*Figure 9. Map of physical-chemical status of surface waters (VGT2, 2015)*

85% of the assessed water bodies is in “good” status, while 15% of them is in “failing to achieve good” chemical status. But for approx. half of the surface water bodies there is no water quality information at all because of the weaknesses of monitoring priority substances. These water bodies are appearing in the status assessment as „grey” (unknown quality) water bodies. The not good quality is caused by exceedances of the EU determined environmental quality standards (EQS) of different compounds and elements, mainly in case of anthracene, diuron, endosulfan, fluoranthene, mercury, cadmium, nonylphenol (h4-nonylphenol), lead and trichloromethane. Most frequent problem is caused by metals, mainly by mercury and cadmium. The big lakes and the assessed oxbows, saline lakes and drinking water reservoirs are generally in good chemical status.

According to the integrated classification (determined by the worse of ecological and chemical status) the upper sections of small rivers in hilly areas generally have good quality status. The quality of Danube and the Tisza rivers are in moderate status while Balaton, Fertő and Velence lakes are good status.

In 2010-14 period 240 designated bathing sites were also assessed against the special bathing water quality requirements, taking into account the human health aspects (e.g. microbiology), as well. At 174 bathing sites the quality was good, and 56 % of the beaches was in excellent quality. In the investigated period only 6 cases were found where the water quality was non-acceptable and prevented the bathing.

The most important recreation area of Hungary is the Lake Balaton, which is today in good ecological and chemical quality, and its beaches are also in good or excellent quality. Perhaps one of the best examples for illustrating the success of water protection measures is the improvement of the lake's water quality during the last decades. The nutrient and organic pollution reduction programs started decades ago covering the whole watersystem of the lake. As a result of these programs, the eutrophication process was pushed back, the biological balance of the lake was stabilized. During the last years the late summer algae blooms, which were frequent in the 1990s, practically have not occurred, due to mostly the effect of wastewater collection and treatment program, which was extended to the whole Balaton catchment area. Some part of the collected wastewaters was led out from the basin. The rehabilitation program of the large wetland area of the Balaton watershed, the so called "Kis-Balaton (Small Balaton)", and the establishment of the filtration systems at the mouth of inflowing creaks had significant effects on reducing nutrient and organic loads of the lake.

The quality of surface waters is negatively influenced from time to time by accidental water pollution cases (havaria), when during a short period time, an extreme amount of pollution far above the usual pollution load level reaches the water. Many times these events have foreign origin. One of the most memorable cases happened in the beginning of 2000, when from the Romanian part of the Tisza River Basin huge amount of mining origin sludge with high cyanide concentration had been spilled into the river causing severe damages in the ecological system of the river.

### Groundwater

As a consequence of non-careful municipal and economical activities the pollution of shallow groundwater lying under most of the built-up areas prevent the use of shallow groundwater for drinking water purposes already in the 1920s. The nitrate pollution of the shallow groundwater layers was gradually increasing under most part of the agricultural cultivated areas, due to the intensification of the agricultural activities (e.g. spreading the animal farms with liquid manure, increasing use of fertilisers) in 1960-70s years. On more and more areas pollutions of soil and groundwater were discovered (e.g. surroundings of gas stations), and it became obvious, that the pollution of shallow groundwater endangered the deeper aquifers, as well.

In Hungary there are some water quality parameters, which have relatively high natural background level, and the anthropogenic activities can increase them, as well. Quality problems of natural origin are due to dissolved iron, manganese, ammonium and arsenic concentrations higher than the standards particularly in porous aquifers. Karstic and bank-filtered water show fewer problems, though they are rather vulnerable.

Integrated status assessment including quantitative and chemical status of groundwater was carried out on the basis of WFD requirements in 2009 for RBMP1 and in 2015 for RBMP2. On the basis of the 2015 assessment out of 185 designated water bodies 53% of them was in "good", 14 % was in „good but at risk" while 33% in "poor" status *(Fig. 10).*

Generally, the diffuse pollution (mainly higher nitrate concentration) is the main cause of the pollution of groundwater. Altogether 2338 water samples were taken and analysed in 2008-2013 to detect pesticide pollution, which covered 80 different pesticides. None of the sampled water bodies was qualified as poor or "good but at risk". Even some improvements could have be detected, compared to previous reviews, but still the vulnerability of shallow groundwater is higher than the deeper aquifers.

Though some measured concentrations of the monitoring wells showed higher numbers to threshold values for pollutants originating from point sources (e.g. sulphate, chloride, metals, PAH, VOC), but the result of a more detailed assessment clarified that because of the scale and point-source character of pollution these do not represent significant problem.

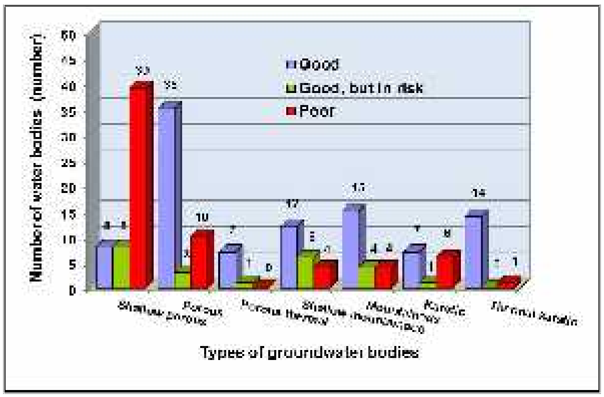


*Figure 10. Integrated status of groundwater (VGT2 2015)*

The status of the protected areas of vulnerable drinking water resources was assessed with special attention, because the pollution of these water bodies can cause health problem. The test results of the production and the observation wells located within protected areas indicated that 20 groundwater bodies were in poor status. In general, the nitrate pollution with municipal and agricultural origin is the typical pollution type that can be detected in the observation wells.

The statistical trend-assessment showed that 15 groundwater bodies were in poor or „poor but at risk" status, because of the statistically significant increasing trends of some pollutants, mainly nitrate and ammonium. The intrusion tests were in connection with the assessments of significant quantitative and long term quality changes. On the basis of these tests it can be stated that the nitrate pollution has not reached the deeper porous aquifer layers, furthermore the quality changes in the thermal karstic water bodies have not reached the level when further measures should be necessary (e.g. introducing new technologies or finishing water use).

## PROGRAM OF MEASURES FOR WATER QUALITY PROTECTION

During the last twenty years many programs, measures and investment projects have been started and implemented in Hungary, which decreased the nutrient-, organic- and hazardous chemical pollution levels of surface and groundwater. Some of them improved the hydromorphological conditions of surface waters and supported the more sustainable uses of water resources. These programs significantly contributed to the improvements of the water quality, comparing to the status observed in the 1960-80 period. From these programs the most important actions were:

- Improvement of municipal wastewater collection and treatment situation of agglomeration above 2000 PE, by implementing the scheduled tasks of the National Wastewater Collection and Treatment Program.
- Set up strategy and launch of a program for hazard-free disposal and recycling of municipal sewage sludge.
- Development of “natural treatment” technologies of wastewaters, incentives and subsidies for extension the uses of installations with environmentally friendly wastewater treatment technology in smaller settlements.
- Improving the quality of drinking waters (tap water) with implementation of National Drinking Water Improvement Program.
- Launching and implementation of the Drinking Water Sources Protection program, designation of protection zones on these protected areas.
- Reduction of diffuse nutrient and other type of pollutions from agricultural origin. Implementation of the relevant EU legislations (nitrate and pesticide directives), designation of nitrate protection areas and protective zones, building manure storages, applying the Good Agricultural Practice on protected areas.
- Set up inventory of historically polluted sites, risk assessment of the pollution. Launching the National Environmental Remediation Program, cleaning up the most polluted sites (including abandoned mines, outdated municipal and industrial waste disposals, etc.).
- Introducing the integrated pollution and prevention control (IPPC) principle into authority practise on permitting and controlling the operation of large industrial and other type installations.
- Implementing complex water protection investments at the priority water protection areas (e.g. Kis-Balaton, Balaton, Ráckevei-(Soroksári) Danube branch, Upper-Danube section) taking into account the ecological water needs.
- Development and operation of monitoring networks and information systems.
- Active participation in the international cooperation on the water protection field, in the frame of the bilateral transboundary agreements with neighbouring countries, the activities of ICPDR and the UN ECE Water Conventions. Participation in the EU Water Framework Directive Common Implementation Strategy (WFD CIS) process.

All these programs are important elements of the Program of Measures of the Hungarian River Basin Management Plans. The second river basin management plan (RBMP2) was adopted by the Government in March 2016. The Program of Measures of this plan determines all horizontal, regulatory, institutional, technical and investment measures, which full implementation by 2027 could ensure that all Hungarian surface and groundwater bodies will reach at least the good quality status *(Fig. 11)*.

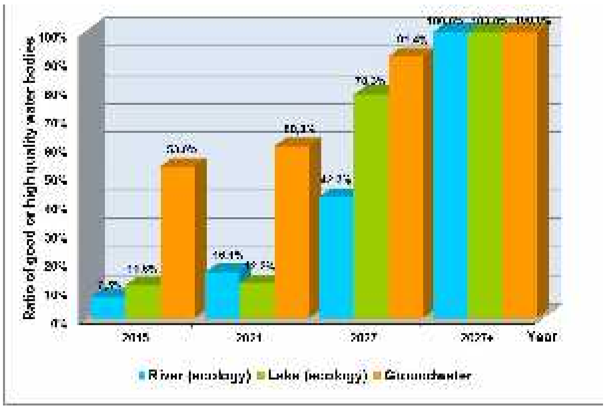


*Figure 11. Timetable of achieving the environmental quality objectives of water bodies (VGT2 2015.)*

## FUTURE TASKS

This paper presented in detail that during the past decades broad range legislation system and the relevant institutional system were set up in Hungary, which ensure the protection of surface and groundwater resources. Today the general quality status of our water resources is not far from the good status. Most of them are in acceptable or even better condition. But despite of this fact lots of tasks are still to be accomplished, which would be necessary to achieve the targets by deadlines. The next subjective – if this is allowed to the Author - findings should be carried out in this regard:

- The strategies, plans (first of all the RBMP2), which determined the water protections’ targets and their deadlines already exist. The WFD compatible environmental quality objectives for waters were determined, and approved on high political level: to reach the good quality of waters by implementing all the necessary measures by 2027. (This target can be considered also, as total fulfilment of SDG 6.3 goal.)
- The basic legislation schemas – to help and guarantee the fulfilment of these quality targets - are also basically laid down. Only fine-tuning is necessary from time to time, but much better implementation of the existing legislation required to achieve the goals.
- The authority and other institutional systems dealing with water protection relating tasks have

to be strengthened and stabilised to improve the quality of permits and intensify the authority controls on operators, as well as improve the monitoring of water status.

- More financial sources are necessary from state budget to support the operation of water protection authorities and other relevant organisations and to finance the implementation of program of measures specified in river basin management plans. The cost recovery principle should be enforced in the financing system of the state institutions and programs of measures.
- Much better co-operation is necessary with other sectors to ensure more effective integration of the water protection policy into regulation, strategies and incentive-systems of other economic sectors.
- During the „classical" type of water management interventions, investment programs, the interest and aspects of water, nature and ecosystem protection should be taken into account more effectively.
- The involvement of the public and stakeholders into planning and implementation processes should be more effective, promoting the improvement of the environmentally conscious thinking and behaviour of public on the field of water protection.
- (Re)establishment of the scientific background institutional system for water management is urgent.
- Active and effective participation in international water co-operations also needs more expert-background and institutional capacity and more financial sources.

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## THE AUTHOR

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# Water bodies in Hungary – an overview of their management and present state

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**Abstract**
Due to its geographical position and climatic characteristics Hungary has many types of surface waters ranging from large rivers to small streams, or from large steppe lakes to small soda pans. These waters have diverse flora and fauna, and provide various ecosystem services for human well-being. Differences among the water types in size, depth, chemistry or biology determine their differential responses to anthropogenic disturbances, and thus their restoration or protection requires different management strategies. With this study the authors aim to review the water-related problems had to be faced and resolved by the experts during the last centuries, and show the achievements reached in the field of water quality management in Hungary.

**Keywords**
Water types, pollution, restoration.

## INTRODUCTION

Waters of the Carpathian Basin played a significant role in the evolution of the landscape, and thus, in the socio-economic life of the population. The ancestors of the Danube, Tisza and Drava rivers created the Great Hungarian Plain which is one of the largest alluvial plains in Europe, covering an area of approximately 100,000 $km^2$. Due to the low runoff and partly to human activities extended wetlands developed on the river flats, which occupied more than 20% of the plain up to the middle of the19th century. At this time, the increasing demand for arable lands and improvement of transport infrastructure (roads and railways) in the Tisza valley required to initiate one of the largest river regulations in Europe. As a result of this comprehensive engineering work many meanders were cut off, the straightened rivers were embanked and the wetlands were drained. Now the length of the embankments and the extension of the area protected from the floods are larger than those in the Netherlands. Although extension of the water-related ecosystems decreased in Hungary during the last two centuries, many unique types of water bodies still can be found here (*Borics et al. 2014*). Lake Balaton, which is the largest shallow lake in Central Europe or Lake Velencei and Lake Fertő, which are the westernmost representatives of the large saline steppe lakes of the Eurasian steppe zone have high conservation value and play important role in the economy of the country. The remaining wetlands, hundreds of oxbows, artificial reservoirs and pit lakes are characteristic parts of the landscape and have also significant local interest. The astatic soda pans constitute a special type of the inland saline waters. Effective managing of the conservation and rational use of the various types of waters is a really challenging task for the experts, because these tasks require type or site specific approaches. The aim of this study is to give an overview of the relevant types of waters in Hungary, and to show the results of those measures that were implemented to restore and improve their quality.

## RESULTS

### River Danube

The Danube is the second-longest river of Europe (after the Volga River), originating at Donaueschingen, Black-Forest (Germany) where the two small creeks, the Breg and Brigach confluence (*Liepolt 1967*). Then the Danube flows southeast for 2,850 km, passing through 10 countries including Hungary before entering the Black Sea. The Danube flows through many cities, including four national capitals (Vienna, Bratislava, Budapest and Belgrade) more than any other river in the world. Its banks, lined with castles and fortresses, formed the boundary between great empires, and its water served as a vital commercial highway between nations. Since the completion of the German Rhine–Main–Danube Canal in 1992, the river has been part of a trans-European waterway from Rotterdam on the North Sea to Sulina on the Black Sea, ranging a distance of 3,500 km.

The Danube enters Hungary at the Little Alföld plain. There the river stream slows down abruptly and loses its transporting capacity, so that enormous quantities of gravel and sand settle on the bottom. Later Danube enters the Visegrád Gorge, the wooded hills of Pilis, Visegrád and Börzsöny. The meandering Danube created a wonderful landscape that became nature lovers' paradise. The Danube then flows through Budapest, and across the vast Great Alföld plain. The whole area of Hungary is the part of its drainage basin. The length of the main channel of the river in Hungary is 417 km, therefore the Danube is the dominant element of the country's hydrography. The natural regime of river runoff changes constantly as a result of the introduction of stream-regulating equipments, including dams and dikes such as the Gabčíkovo Dam. Because of the dam we have to face the following environmental consequences: intensive degradation of the Danube River bed downstream (especially at the Old Danube river bed); decreased water level; increased sediment supply; increased amounts of bedload and higher intensity of bedload movements; reduced flood capacity; decreased channel stability.

Tourism and natural spots are important along the Danube. Also especially travel cruises and shipping transport on the river are of significance, especially on the frequented route between Vienna and Budapest. The Danube Banks in Budapest are a part of Unesco World Heritage sites; they can be viewed from a number of sightseeing cruises offered in the city. Despite extensive development of Hungary some of the original floodplain ecosystems survive (*Fig. 1*). Reminders of the primeval landscape, floodplain forests such as those in Gemenc area of Hungary provide habitats of birds, e.g. white-tailed eagle, black stork, black kite, night heron.

*Figure 1. Danube River at Göd*

Today, we should find the harmony between the shipping, drinking water and energy production, recreation needs - to mention only the most important ones - although these issues require different management approaches. One of the main problems is the establishment of reservoirs of the power plants, which hold the suspended solids and debris, and thus lower the river bed at the downstream sections, which hampers the water supply of Budapest. It can also be observed in Gemenc region where as a result of the decreasing water level, the side arms detached from the main channel and now form a typical backwater.

In the 1950s, '60s due to the industrial development and to the increasing use of agricultural fertilizers the Danube became enriched with nutrients. In the 1960-70s large-scale power plant dam construction programs began, which meant a drastic reduction in rolling and transporting suspended sediment. The suspended solid deposition resulted in improved light conditions, so in addition to the abundance of plant nutrient supply, significant eutrophication (algae) occurred (*Kiss 1994, Kusel-Fetzmann et al. 1998*). At the Hungarian section in 1980s the chlorophyll-a concentration was often larger than 100 $\mu gL^{-1}$, and even the yearly average often reached or exceeded the 50 $\mu gL^{-1}$ (*Fig. 2*) caused mainly by centric diatoms (*Kiss et al. 2012*).

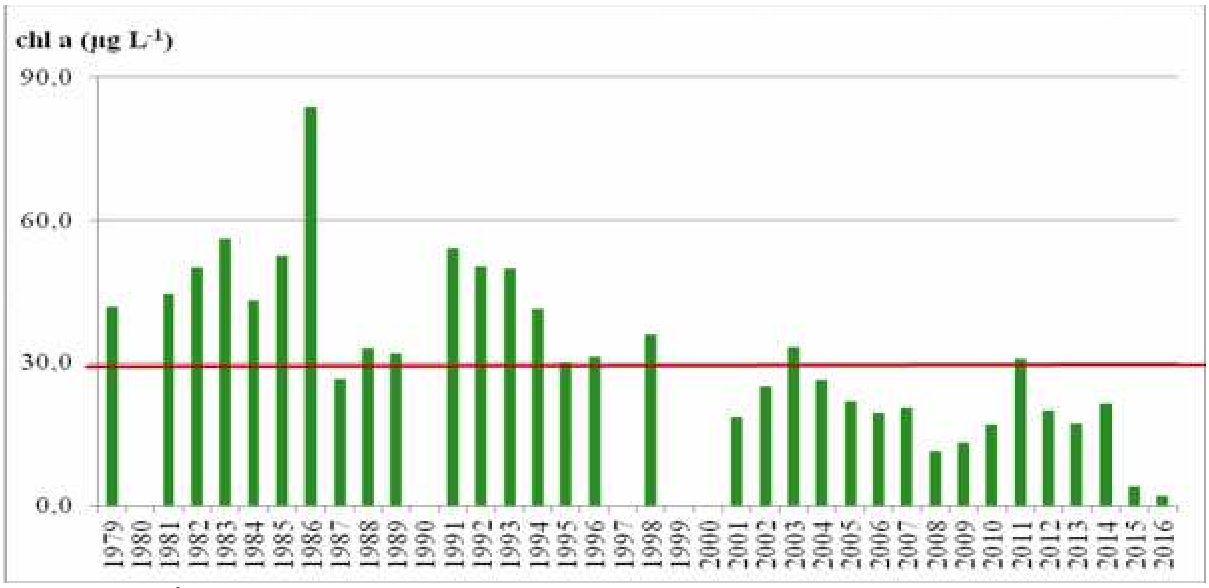


*Figure 2. Changes of yearly average chlorophyll a concentration in Danube River at Göd, measured in the vegetation periods. Red line indicates the good/moderate border*

The values in the Szigetköz and Gemenc side arms sometimes reached 200-300 $\mu gL^{-1}$. After the political changes at the beginnings of 1990-es the industrial and agricultural production has fallen significantly, which considerably reduced the use of fertilizers. Thanks to the European Union Water Framework Directive a lot of big cities, municipalities developed an effective wastewater treatment. As a result of these actions, nutrient supply dropped to one third of the previous values and water quality of theDanube started to improve. The largest environmental investment implemented in Central Europe fundamentally modernised the wastewater treatment system of Budapest, ensuring cleaner waters for all those living along the banks of the Danube.

Although eutrofication of the river Danube successfully controlled, in the recent years increasing amount of evidences indicated that other forms of pollutions frighten the quality of the Danube. Various persistent micro-contaminants (drugs, pesticides etc.) which cannot be eliminated in the wastewater treatment plants have become the focus of interest. Increasing occurrence of non-native, invasive organisms means acute problem in the Danube river valley, because these taxa can be disease carriers or occasionally replace the elements of the native flora and fauna causing ecosystem-level changes and undesirable consequences.

**Tisza River**

The Tisza takes its source in the Eastern Carpathians (Ukraine) crosses the Great Hungarian Plane and finishing its 962 km long route enters the Danube in Serbia. Development of the present state of the Tisza valley can be dated back to the mid-19th century when comprehensive regulation of the river started. The originally 1419 km long river has been shortened, embanked, and more than 20,000 km$^2$ area became protected from floods. Besides the positive impacts of this huge engineering work negative outcomes also occurred. Drying out of the valley threatened the safety of the agricultural production and became an urgent problem by the middle of the 20th century. This necessitated the building of two river barrages (Tiszalök 1959; Kisköre 1974) and several canals in the middle part of the valley. Although the danger of annually arriving devastating floods has been greatly reduced, deforestation of the upper catchment and the extreme events of precipitation in the Carpathian Basin contributed to the development of extreme floods and low discharge periods in the recent years (*Fig. 3*).

*Figure 3. Forest on the Tisza floodplain (Photo: Béla Csányi)*

These new challenges required the rethinking of previous measures and called into being new strategies in river management. Several off-river storage reservoirs have been planned and established in the middle Tisza valley to reduce floods and to store water in dry periods. Despite the engineering works substantially altered the landscape in the Tisza valley the river and its immediate surroundings managed to preserve their natural character. Although the large wetlands that formerly characterised the Tisza valley have been drained, many water related natural and semi-natural areas have been preserved, restored or established newly, which act as green corridors.

Due to urbanization, industrial development and the intensification of agriculture water quality of the Tisza and its tributary rivers considerably worsened from the middle of the last century. The untreated sewage effluents caused drastic organic and (after their degradation) nutrient load, which led to the eutrophication of the rivers with its all negative consequences. This negative tendency changed from the 1990-ties when several factories were closed and hundreds of sewage treatment plants were established in the region. The water quality and ecological state of the river considerably improved. The enhanced recovery potential of the Tisza river is clearly indicated by the quick recovery of the biota after the serious cyanide pollution that occurred after an industrial accident in Romania in 2000.

**Small streams**

During the comprehensive regulation of rivers in the Tisza valley the flooded areas in plains were almost totally eliminated. The landscape has been affected by the digging of ditches and the drainage of wetlands for agriculture. Lowland streams have been straightened, deepened and widened to facilitate land drainage and to prevent local floods. Consequently, the trees in the shoreline were diminished, buffer zones were eliminated and the level of groundwater decreased.

These small streams are vulnerable to changes that anyway have little effect on larger water bodies. They have sufficiently large catchment area to be adversely affected by human impacts. Small rivers with a small volume of water have only a limited ability to dilute and retain pollution, and therefore they are highly susceptible to inputs of pollutants from their surroundings, such as nutrients and pesticides from agriculture. Excessive sediment movement caused by erosion of streambed is also a factor affecting the ecological status of water bodies, particularly in small lowland streams. In addition, dry periods and water abstractions can greatly reduce their water flow and water level. Therefore, these small streams generally have poor ecological quality.

There are, however some parts of the Tisza valley where the small lowland streams were less affected by human impacts (*Fig. 4*). The streams which show the features of former natural ones represent unique and important ecological systems. They support specific and important hydrological, chemical and biological processes and provide proper habitats for a wide spectrum of plants and animals. However those few small lowland streams that are still in good ecological state are also exceptionally vulnerable to climate change impacts. The increasing water temperature and the likelihood of water scarcity and droughts can seriously affect the ecological status of small streams.

*Figure 4. Small lowland stream in natural state*

Unfortunately, achieving of the good ecological status of the small lowland streams in Hungary, among others, is impeded by the low stream gradient (slope of the stream), flow periodicity, fluctuation of water level, relatively low water depth, excessive water abstraction and lack of buffer zones. Although there is now an urgent need to pay more attention to the conservation-oriented management of small streams, it is in conflict with the objectives of the agriculture.

**Lake Balaton**

Lake Balaton – the largest lake of Central Europe – lies almost exactly in the centre of Transdanubia, the ancient Roman province of Pannonia. The mean lake level is 104.8 m above the Adriatic Sea level. At mean lake level the surface area is 596 km$^2$, the mean depth is 3.25m, so that Lake Balaton is a shallow lake having a large surface area. This lake has an elongated shape with a length of 78 km and an average width of 7.6 km. Along the longitudinal axis the depth decreases gradually to the SW-end. The northern shore decorated by a range of picturesque hills (extinct volcanoes in the Tapolca basin) (*Fig. 5*) while its southern shore is a fertile flatland.

*Figure 5. Lake Balaton with extinct volcanoes in the background*

The southern shore is a sandy beach, the bottom drops steeply here, along the northern shore, the bottom of the lake deepens sharply. The catchment area covers 5775 km$^2$. The lake has 51 inflows but the only outflow is the Sió Canal at the south-eastern end of the lake. One-half of the inflow iinto the lake is the River Zala, which flows into the smallest westernmost basin. The Zala River drains an area of 2622 km$^2$.

Limestone and dolomitic rocks predominate in the catchment area, consequently the waters discharged the lake predominated by calcium-, magnesium- and bicarbonate ions. The concentration of total dissolved solids is quite high, about 500 mg/L, and the typical pH of the water is 8.4. Almost one-half (110 km) of the shoreline covered by a dense reed stands. The total area of the reed cover is 15 km$^2$ (*Herodek et al. 1988*). The water temperature is normally above 20 ºC from the end of May to early September, and this period is considered suitable for bathing and aquatic sports. Lake Balaton is one of the greatest natural assets and main touristic destination in Hungary due to its sweet water, mild climate, and picturesque landscape. The eutrophication of Lake Balaton has become a serious problem in the eighties of the last century. Summer blooms of nitrogen-fixing filamentous cyanobacteria became frequent phenomenon in the western part of the lake, as a consequence of the large phosphorus load of River Zala. The large scale eutrophication control measures (sewage water diversion, phosphorus removal at the sewage treatment plants, construction of pollution control reservoirs on the catchment area) resulted in a significant decrease of the external phosphorus load and phytoplankton biomass of the lake (*Clement et al. 2005*). During the 1980s the summer maximum of the chlorophyll a concentration usually exceeded the 200 µg/L, nowadays it is far below the 50 µg/L in the most productive western basin, which means that the whole lake is suitable for bathing (the WHO limit is 75 µg/L in case of cyanobacteria dominance) (*Fig. 6*).

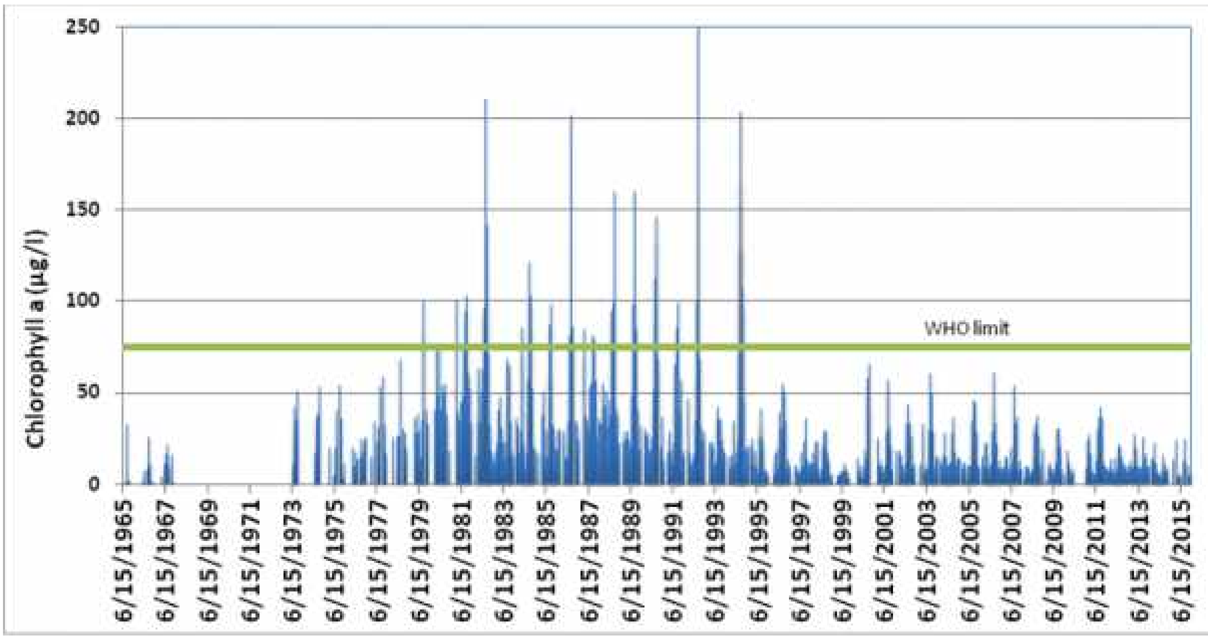


*Figure 6. Long-term changes of the phytoplankton biomass (chlorophyll a concentration) in the most productive western basin of Lake Balaton*

**Lake Fertő**

Lake Fertő/Neusiedlersee is a wind-exposed, extremely shallow steppe lake (~ 1.3 m), straddling the Austrian-Hungarian border at 166.5 m above Adriatic Sea level (*Löffler 1979, Dokulil and Herzig 2009*). The lake basin covers a total area of 315 km², of which 76% (240 km²) are on the Austrian and 24% (75 km²) are on the Hungarian territory. The lake has an elongated shape with a maximum length of 36 km and a maximum width of 12 km. Two major inflows are River Wulka and Rákos stream. Originally, the lake has no natural outflow, but at the end of the 19th century an artificial channel (Hanság channel) was constructed. Nowadays, the lake water level is regulated by a sluice on Hungarian territory near Fertőújlak, and bilateral issues are dealt with by the Austro-Hungarian water commission which was established in 1956 (*Loiskandl et al. 2012*). In the 18th century the lake had dried out four times and the last vanishing was from 1864 to 1870 (*Loiskandl et al. 2012*).

More than half (ca. 55%, i.e. 171 $km^2$) of the surface area is covered by emergent vegetation, mainly reed (*Phragmites australis* (Cav.) Trin. ex Steud). In Hungary, reed comprises a significantly larger area along the shoreline (up to a width of >5 km), than in Austria (up to 2 km). Degradation of the reed stands has been documented from the early 1980s (*Dinka et al. 2010*).This problem is more aggravated in the Hungarian part: while in Austria only 10% of the reed stands are degraded, in Hungary this proportion is 30% (*Márkus et al. 2008, Wolfram et al. 2014*). As a result, there are numerous reedless brown-water ponds (inner lakes) of variable size within the reed belt, which is intersected with artificial canals connecting the inner ponds with the open water areas (*Fig. 7-8*). Electric conductivity is about 2,200 $\mu Scm^{-1}$, and the pH varies around 9. The dominant salt is sodium bicarbonate ($NaHCO_3$) and thus, Lake Fertő classified as a soda lake (*Wolfram et al. 2014*). As a result of wind-induced sediment resuspension, the open water of the lake is characterized by high inorganic turbidity and usually low Secchi-disk transparency (*Löffler 1979*). Within the reed cover, water is not turbid due to less exposure to wind and brown in colour due to humic substances (*Löffler 1979, Wolfram et al. 2014*).

*Figure 7-8. The open water and the reed belt of Lake Fertő/Neusiedlersee*

The lake underwent strong eutrophication during the 1970s and 1980s, when phosphorus concentrations have shown a pronounced rise due to increase in tourism and economic development in the catchment as well as an enhanced consumption of fertilisers in the intensified agriculture (*Dokulil and Herzig 2009, Wolfram et al. 2014*). In the open water, annual mean concentration of total phosphorus rose from about 40 $\mu gL^{-1}$ to more than 160 $\mu gL^{-1}$ at the peak of the eutrophication period (*Wolfram et al. 2014*). Due, however, to extreme light limitation of algae, enhanced nutrient availability did not induce a significant increase in phytoplankton biomass, and algal blooms were mainly restricted to sheltered areas. Various management measures were taken to reduce the nutrient input into the lake. These have significantly reduced anthropogenic nutrient loads since the beginning of the 1980s. Total P loads fell from about 80 t in the beginning of the 1980s (only Austrian part of the catchment area) to less than 20 t around 2000 (total catchment area). As a consequence, phosphorus concentrations have also decreased since the 1980s (*Wolfram et al. 2014*).

During the last century, the fish community has experienced significant changes, mainly due to fisheries and introduction of exotic species (topmouth gudgeon, pumpkinseed). Stocking with eel was clearly one of the most serious impacts on the autochthonous fish community from the middle of the 20th century (*Wolfram et al. 2014*). It resulted in local extinction of small-sized fish, like mudminnow and weatherfish. Since the beginning of the 21st century, when stocking of glass eel was stopped, the density of eel has significantly decreased. Recently, species, which had become locally extinct, were re-introduced in the Hungarian part of the lake, e.g. the weatherfish (*Wolfram et al. 2014*).Today, there are less than 15 professional fishermen in Austria, while about 40-50 of them worked in the whole lake at the end of the 19th century. Angling and fishing on the Hungarian side has never been as important as in Austria, due to the large extension of the reed covered area.

Because of the environmental diversity the Lake Fertő region provides habitats for many wildlife species especially birds and an important wetland in Central Europe. For conservation and wise use of the wetland and its resources the “Neusiedler See-Seewinkel” is designated to the Ramsar Convention on Wetlands in 1982. Aside from that, for nature and natural resources conservation a national park “Neusiedler See-Seewinkel” was founded in 1993 and co-managed with the Hungarian national park “Fertő-Hanság”, founded in 1991 (*Loiskandl et al. 2012*).

**Lake Velencei**

Lake Velencei, having unique value from geological, nature conservational and ecological viewpoint, is the second largest soda lake in Hungary (area: 24 km$^2$, mean depth: 1.6 m; Electrical conductivity: ~3000 µS cm$^{-1}$) and an important touristic and recreational centre (*Reskóné 1999*). In the past the lake was characterised by drastic water level fluctuations; occasionally dried up, or since it has no natural outlets, flooded its surroundings. To lower these extremities the first interventions were implemented in 1880 when the extended wetlands on the south-western part of the lake were drained and a natural outlet was established, by which an effective water level regulation could be achieved. From the 1930s due to the development of holiday resorts around the lake the anthropogenic effects became more intense, accelerating the process of natural eutrophication that was already in advanced stage independently of anthropogenic load. The reed-bed proliferated more and more both along the shore and in the inner parts of lake-basin and the mud that accumulated in the midst of roots of the reed arrested the movement of the floating marshes that were characteristic formations of the western part of the lake. (*Gorzó 1990*). By the beginning of 1960s, the 59% area of the lake was already covered by reed, while in the open water areas the mass proliferation of algae resulted in water blooms; which frightened tourism and water uses. To overcome these undesirable processes a comprehensive rehabilitation of the lake (reed-cutting, dredging of the basin and shore regulation) started in the 60ties. In the course of dredging, 9 million m$^3$ of mud was removed from the basin. This mud was used for banking up one part of the shore and creating two small artificial islands. Parallel with this a shoreline regulation (1962-1985) was also done. In the catchment area of the lake two reservoirs were built, which can supply the lake with water in dry periods. Due to these measures the water level of the lake can be regulated safely.

At present, Lake Velencei can be divided into two, clearly separable parts. The reedy-marshy Bird Nature Reserve of the western basin (*Fig. 9*) covers approximately one-third of the lake. The other, eastern part turned into a large, open water area (*Fig. 10*) after the reconstruction, and now it is an important recreation area. Despite the measures taken during the last decades several problem still have to be faced, i.e. cyanobacterial blooms, or occasionally occurring imbalance between the wetland and open water areas of the lake, which creates undesirable processes concerning the lake's chemical and biological processes (*Reskóné and Törökné 2000, Reskóné et al. 2001, Ács 2007*). These highlight the need for deeper understanding and protection of the delicate biological system of the lake.

*Figure 9-10. The Western (laeft) and Eastern (right) parts of the Lake Velencei with wetlands and open water areas*

**Soda pans**

Soda dominated waters are characterized by large amounts of sodium hydro-carbonate/carbonate and usually hypersaline with high alkalinity (pH>9), which property clearly distinguishes them from other inland saline waters. Soda lakes/pans can be found in each continent of the World, but their distribution is confined to specific geographic regions. The Carpathian Basin is the western border of the soda lakes/pans distribution (Austria, Hungary and Serbia) in Eurasia, and they can be found only in few regions of Asia. The intermittent (astatic) soda pans are very shallow (water depth >1m) and small (open water 1−200 ha), which were formed on various geological substrates by specific climatic, geologic and hydrologic environment in the Carpathian Basin at the end of Pleistocene and the beginning of Holocene, which were influenced by human impact in the last two centuries. The intermittent soda pans are situated in the groundwater discharge areas of a closed hydrographic (endorheic) basin, in which groundwater inflow exceeds the surface-related watershed inflow and precipitation.

The most important ecological criteria of the intermittent natural soda pans are listed below (*Boros et al. 2014*):

- Shallow astatic open water bodies with bare pan bed (emerged and submerged macrophytes are sparse or absent);
- Annual average of salinity exceeds 1 g/L;
- The presence of characteristic species of flora and fauna.

The most frequent type of soda pans is the basic alkaline type (Na-$HCO_3$), the second and third subtypes are the chloride and sulphate, beside the hydro-carbonate/carbonate dominance. Magnesium sometimes arises as a secondary dominant cation beside sodium.

Salinity varies widely in sub- (0.5–3 g/L) and hypersaline (>50 g/L) ranges, while the pH varies in 8–10 range. Beside the high alkalinity, the high inorganic turbidity (Secchi depth 0.5−30 cm), polyhumic concentration of dissolved humic substances, hypertrophic conditions of the soda pans represent a unique aquatic ecosystem in Hungary (*Boros et al. 2013, Boros et al. 2014*) (*Fig. 11*).

*Figure 11. Soda pan in the Danube-Tisza Interfluve*

Due to their lower salinity, biodiversity of soda waters is generally higher than other continental saline waters with characteristic flora and fauna, benthic and planktonic communities reflect a strong structuring role of salinity, turbidity and trophic state, and the intermittent standing water incapable of supporting resident fish populations. The characteristic soda pan habitats are listed in Annex 1 of the EU Habitat Directive (92/43/EGK) and are thus considered to be of high priority (Natura 2000 Network). Coupled with the characteristic physical and chemical conditions the waterbirds have an important role in the regulation of trophic relationships of the soda pans (*Boros et al. 2008a, Boros et al. 2008b, Vörös et al. 2008*), and several of them have been designated as Wetlands of International Importance by the Ramsar Convention on Wetlands and as Special Protection Areas for birds. Because of the significant (85%) loss of these habitats during the last 60 years in the Carpathian Basin, they are “ex lege” protected in Hungary. Due to to unstable water balance and small size these pans are particularly threatened by the climate change combined with human activities.

### *Oxbow lakes*

The oxbows are characteristic parts of the landscape in the Great Hungarian Plane. Although some of them are formed naturally, most oxbows were created in the second half of the $19^{th}$ century, during the comprehensive regulation of rivers in the Tisza valley. More than 100 meander loops were cut off, resulting in hundreds of oxbows with a total length of 589 km and with an area of about 3000 ha. Oxbows of the floodplain are quickly filled with sediment, but those ones which are separated from the watercourses by flood protection embankments can keep their open water character for centuries. (*Fig. 12*)

Now the oxbows in Hungary occupy the complete range of successional stages, from the relatively deep open water lakes to the shallow marshlands (*Krasznai et al. 2010*) and provide habitats for many rare and protected plants and animals. However, oxbows are very sensitive ecosystems. Most of them have left their direct contact with the living river, and thus, total exchange of water in the lake basin with fresh water is not possible. The other important hydromorphological characteristic of these lakes is the small surface area to shoreline ratio which means, that oxbows are extensively exposed to anthropogenic disturbances.

*Figure 12. Oxbow lake at Tiszadob village*

Ecological state of these water bodies is strongly determined by the type of land use in the immediate catchment. Oxbows surrounded by arable lands are the most threatened because of agricultural diffuse pollution from fertilisers. The enhanced nutrient input accelerates the filling succession of the lake basin, and drives the system towards an unstable hypertrophic state, which is characterised by dense marshy vegetation and extreme values in water quality. The other threat to the oxbows is the intensification of sport fishing, which coincides with the drastic artificial modification of the fish fauna, increased pollution caused by the feeding of fish, and ultimately, with enhanced algal blooms (*Borics et al. 2013).* Several oxbows were dredged and restored in the recent years, and now because of their unique flora and fauna many of them are under nature protection. However the multiple uses of these waters results in conflicts between stakeholders (local residents, fishermen, conservationists, agriculturists), therefore restoration and conservation of these valuable aquatic systems will require the development of comprehensive ecologically-based management strategies in the near future.

### Wetlands

Great Plain wetlands are remnants of the former extensive floodplains of river Tisza and its tributaries. Before river regulation (mid-$19^{th}$ century), inundation by floods was part of the natural dynamics of the vast Tisza floodplain. Floods represented periodically occurring disturbances that led to the formation of a mosaic of habitat types ranging from constant marshes through periodically flooded marshes to irregularly flooded marshes and meadows (*Aradi and Lengyel 2003*). Descriptions from the $18^{th}$ and $19^{th}$ centuries attest that floodplain wetlands were used for fishing, egg collecting, plant collecting, reed harvesting and livestock grazing. Regular floods and the variety of land use ensured that the mosaic habitat complexes of wetlands hosted highly diverse communities of plants and animals on which people depended.

Today, Great Plain wetlands are the last representatives of the former extensive active floodplains of the Tisza valley. These wetlands provide refuges to a high diversity of marsh and meadow vegetation types and many species, especially of aquatic plants and insects (e.g. dragonflies), some rare fish species (e.g. loaches), amphibians (frogs, toads, newts) and waterbirds (*Aradi et al. 2003*) (*Fig. 13*). The persistence of wetland diversity depends on the quantity and dynamics of water supply and proper management. In the absence of management, constant water supply leads to the homogenisation of the vegetation and reed (*Phragmites communis*) often forms extensive, species-poor reedbeds. National park authorities thus control water supply to mimic the natural flow dynamics of Tisza as much as possible, and introduce management to mimic the disturbances that were once essential in maintaining the diversity of habitats and species.

*Figure 13. Hagymás weltland in Hortobágy*

Cattle-grazing in marshes, a traditional way of managing wetlands has been restored in several lowland wetland areas (Hortobágy, Kiskunság and Körös-Maros National Parks). In addition, burning (prescribed fire) in the late summer, when the reed plant is blooming, is also used occasionally for reed management. Recent studies, however, suggest that burning has only a temporary effect as it leads to the rejuvenation of the reedbed, therefore, it has to be repeated once every two or three years. Cattle-grazing, even in low densities, has a longer-lasting effect because cattle effectively inhibit the growth and spread of the reed through their trampling and reed consumption. A combination of burning and cattle-grazing was effective in increasing marsh diversity, which in turn increased the abundance and number of species of amphibians (*Mester et al. 2015*). Newly burned areas devoid of reed were favoured mostly by waterbirds, and grazed areas were favoured by farmland birds, whereas non-burned, non-grazed areas rich in old reed were favoured by reedbed passerine birds, providing an example for mosaic-like management benefitting several groups of species at the same time (*Mérő et al. 2015*). In recent years, awareness of the combination of pasturing and conventional nature protection actions can be regarded as one of the greatest progresses in wetland management.

**Pit lakes**

The Carpathian basin was filled with heterogeneous fluvial deposits i.e., gravel, sand, silt and clay. Increasing demand of the industry for these materials triggered intensive mining operations in the region. Open cut mining resulted in hundreds of pit lakes that range in area from< 1 to 300 ha surface area,< 10 to 70 m depth and 5-100 years in age. These pit lakes are considered as end use of mining, and serve primarily as recreational areas. (*Fig. 14*) However pit lakes have very special hydro-geological and limnological characteristics, which strongly determine the details of the tools that are applied to restore their quality (*Borics et al. 2015*). Since the fluvial deposits in Hungary are chemically inert materials water quality of the pit lakes are determined primarily by the quality of ground water, which is the most important part of the water balance. The groundwater flow in coarse-grained alluvial deposits is very intensive, which means that any pollution of the catchment area will quickly appear in the water of pit lakes, and vice versa, pit lake pollution directly threatens the quality of the ground water. This is especially important because 90% of the drinking water supply in Hungary is primarily based on ground waters. Pit lakes are deep and have small surface area to depth ratio, which results in stable thermal stratification of the water column. The relatively large water volume can buffer the negative consequences of pollution for a short period of time, and stratification of lakes conceals the undesired processes running in the deep layers and having serious consequences for the lake biota.

*Figure 14. Gyékényes gravel pit lake along the Drava River*

Monitoring, assessment and management of these lakes therefore needs special approaches that are different from those applied for shallow lakes. Many of the large deep pit lakes are still considered the best quality surface waters in Hungary, however without comprehensive management actions their quality can decrease quickly. Recreational fishing, stocking of invasive fish, use of fertilisers in the catchment resulted in adverse processes in several pit lakes which are indicated by enhanced production of phytoplankton and depletion of oxygen in the deeper layers. Local measures have been proposed and implemented in the recent years to protect pit lakes' water quality, but nationwide accepted comprehensive post mining management of pit lakes is still lacking.

**Fish ponds**

Large scale river regulations resulted in a continuous degradation of traditional fishery starting from the 19th century. Fish ponds became the main sources of fish production and utilization, which were established on natural streams and canals (*Specziár and Erős 2015*). Consequently, at present, aquaculture mainly utilizes natural water resources by capturing the water of streams in valley dammed reservoirs and artificial pond systems on an area of cca 25,000-30,000 ha. By far the most important fish species produced in aquaculture in Hungary is the common carp (*Cyprinus carpio*) and the most important supplementary species are the silver carp (*Hypophthalmichthys molitrix*) and the grass carp (*Ctenopharyngodon idella*). Species with relatively low contribution are the pikeperch (*Sander lucioperca*), the Northern pike (*Esox lucius*), the European catfish (*Silurus glanis*), the tench (*Tinca tinca*), the bighead carp (*Hypophthalmichthys nobilis*) and some other, especially Cyprinid or Percid species. Unfortunately, many fish pond systems are age-worn and especially their sluicing is inappropriate to prevent the escape of cultured fish into natural habitats. This yields the escape of non-native species to natural stream segments. Reservoir dams also cause the fragmentation of stream segments. Therefore, one of the greatest challenges of environmental management in future decades will be balancing between multiple ecosystem services including water retention, fishery production, recreational fishing, and biodiversity conservation while also maintaining good ecological status in stream-reservoir systems.

**Kisköre Reservoir**

Kisköre Reservoir is the largest artificial lake in Hungary. The first dam on the Hungarian stretch of Tisza was constructed in 1954 at Tiszalök. The second water barrage system with the Kisköre Reservoir was built between 1967 and 1973. By damming up the section between Kisköre and Tiszavalk, Kisköre Reservoir has been established in the middle stretch of the Tisza, which with its 127 km$^2$ extension has become the second largest stagnant water of the Carpathian Basin. This reservoir was built for a power station and as a source of water for irrigation. Beside these, it functions as an important bird refuge and nature protection area (*Fig. 15*).

*Figure 15. Kisköre Reservoir (nature reserve area)*

The form of the recent image of the Kisköre Reservoir is the result of a longer process, which created isolated water bodies within the system differing sharply from each other in appearance, hydrological and hydrobiological features. Looking at the Kisköre Reservoir from an ecological point of view it can be considered as a shallow-lake type reservoir, of which large scale mosaicity is well represented by marshes, shallow-lakes, water pits excavated by floods, large and medium sized small water courses.

Changes of environmental conditions cause qualitative and quantitative changes of planktonic and benthic elements of the flora and fauna. Because the concentration of plant nutrients in the Tisza river is high, main limiting factors of phytoplankton are the temperature and the suspended solid content. Annual changes of the latter variable can be linked to floods. In flood periods low number of species and individuals is typical. In summer the composition of the plankton is similar to that of other large reservoirs both in terms of number of species and individuals. Benthic fauna of the reservoir can be considered relatively rich in species. Dominance of stagnant water fauna is typical. Similarly to plankton the benthic flora and fauna shows pronounced differences among the basins of the reservoir. Currently about 50 % of the total reservoir surface is covered by plants. In waterweed vegetation of the reservoir water chestnut and in the marshy vegetation reed are stand-forming. Kisköre Reservoir with its diverse natural surroundings is an all-season fishing paradise with high catch rates. It has a wide variety of water depths, the zigzagging canals and the calm water of the reservoir provide ideal habitat for different kinds of fish. Most native Hungarian fish species can be found and relatively easily caught here.

Ecological state of the reservoir is continuously monitored by the water authorities. The filling succession of the reservoir basins is controlled by dredging and cutting of the macrophytes, thus the operation of the reservoir and its services are sustainably ensured.

## DISCUSSION

Although there are many evidences that human activities in the Carpathian Basin had pronounced impact on the waters even in the medieval period, the comprehensive alteration of rivers and lakes started only in the 19$^{th}$ century. The huge wetlands that covered approximately 20% of the Great Hungarian Plain were drained, water level of the large lakes i.e. Lake Balaton, Lake Fertő were stabilised. The large rivers Danube, Tisza and each of their tributaries were regulated and an extended network of channels and embankments were established to satisfy the demands of safety, and the new agriculture, industry and trade. By the end of the 19$^{th}$ century the existing water network had been developed and successfully managed from hydrological point of view, but especially from the second half of the last century the growth of industry, the industrialised agriculture, the overuse of waters resulted in serious pollution in lakes and rivers, which frightened and destroyed the health of the ecosystems and jeopardized the rational use of water resources. As it was shown above solution of these problems required measures that were specific to the type of pollution and to the type of water bodies. Due to these efforts quality of the surface waters has greatly improved in Hungary. However, a number of problems have not been solved yet. The global warming results in several problems i.e., unpredictable precipitation regime and thus water level fluctuation in lakes and rivers, or invasions of alien species both plants and animals that not only endanger the elements of the native flora and fauna, but can cause serious water quality and health problems. These factors mean a great challenge for water management in the near future.

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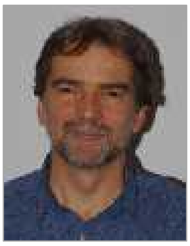

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Hungarian Hydrological Society

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Keverőink és áramláskeltőink komplett választéka az alábbiakat biztosítja:
• Túlméretezés nélküli tisztítási technológiák, melyek csökkentik az energiafogyasztást.
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