Water Europe

Technology & Innovation

THE ROLE OF WATER IN THE ISSUE OF PUBLIC HEALTH

Water Europe

Technology & Innovation

Water Europe

Technology & Innovation

Prologue

Water Europe (WE) is the recognized voice and promotor of water-related innovation and RTD in Europe. WE is a value-based multi-stakeholder association that represents the whole diversity of the innovative water ecosystem. WE was initiated by the European Commission as a European Technology Platform in 2004. All WE activities are guided by its Water Vision and the ambition to achieve a Water-Smart Society.

The Water Europe White Papers are aimed at informing readers about complex water-related topics in a concise and targeted way, and presenting WE's vision and philosophy on the matter. They present evidence-based opinions on multiple water-related challenges and on ways to overcome them. WE White Papers are produced as part of the WE Collaboration Programme by the WE Vision Leadership Teams and the WE Working Groups. They target a wide variety of potential audiences, including the EU institutions, international organisations, the water industry, water users and water-related strategic stakeholders, the economic sectors, as well as media, analysts, regulatory and governing bodies, citizens and society at large

Durk Krol
Water Europe Executive director

Water Europe Vision 2023

The human right to water encompasses five requirements: 1) availability, 2) accessibility, 3) affordability, 4) acceptability, and 5) quality and safety. These must be fulfilled to satisfy the human rights to water and sanitation, and protect the health of users and the general public, regardless of their identity, location or ability to pay.
Adapted from the UN Water website, 2022.

The Water Europe vision for a Water-Smart Society

This Water Europe Vision document charts the pathways towards society's better use, valorisation and stewardship of our water resources, and the development of resilient and sustainable solutions to address our key water challenges. It describes how these challenges can be transformed into opportunities for developing and deploying new European technologies, solutions, businesses and governance models for the Water-Smart Society of the future. It projects a future of comprehensive water security, sustainability and resilience for all societal functions, and of full environmental protection. It is a vision in which all relevant stakeholders are involved in the sustainable governance of our water system, in a way that meets ecological, social and economic needs, without compromising the ability to meet these needs in the future; water scarcity and pollution of European groundwater and surface water are avoided, while biodiversity is restored; water, energy and resource loops are largely closed to foster a circular economy; the water system is resilient and robust against demographic pressure and climate change events; and European water-dependent businesses thrive, thanks to forward-looking research and innovation. Although the vision is focused on the European situation, many of its features are relevant to realising Water-Smart Societies all over the world.

A paradigm shift towards an inclusive Water-Smart Society

The Water-Smart Society envisaged by Water Europe entails a paradigm shift in the way the value of water is recognised and realised, water-smart solutions are developed and deployed, and our future society organised and managed with regard to water. This shift calls for bold and courageous decisions, investments, changes, and new types of stakeholder partnerships at all levels of society, involving citizens, public authorities at all levels, scientists, industries and farmers, as well as the stewards of the natural environment. It will require the development of a dual migration path to introduce both new solutions and governance practices, with the involvement of all relevant stakeholders at urban, regional, inter-regional, national and international level.

The Water-Smart Society will leverage both the dramatically increased manageability made possible by the emerging cyber-physical environment and 'digital water' technologies, as well as the increased availability of 'multiple waters' to complement freshwater sources. It will also be characterised by much deeper levels of awareness, integration and collaboration between organisations and citizens.

Since the migration towards the Water-Smart Society will demand significant investment in redesigned and adapted infrastructure, as well as innovative technologies, it comprises a complex mix of challenges and opportunities for European industry. These will demand a longer-term programme to drive a stable and successful migration towards the future Water-Smart Society.

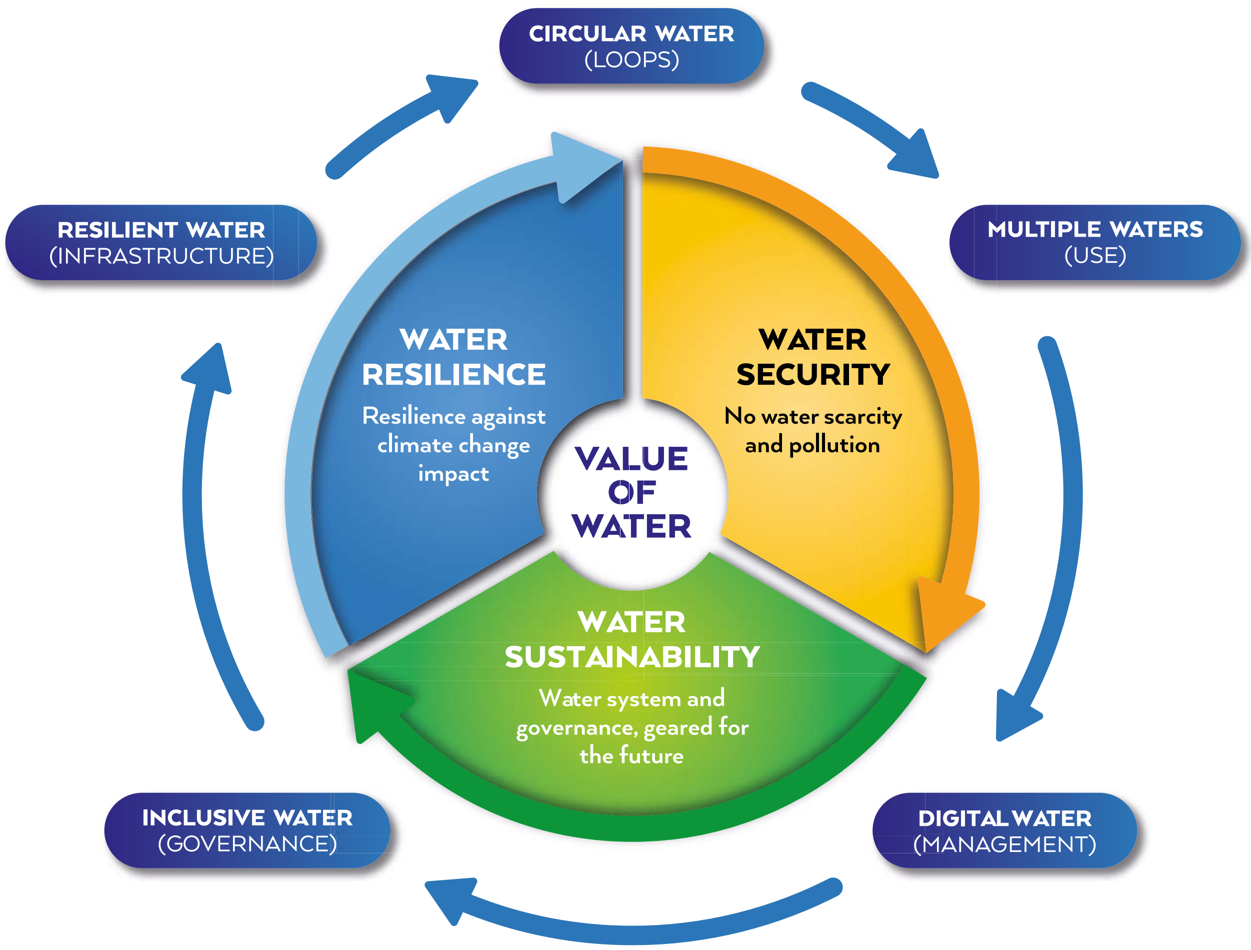
A Water-Smart Society

A Water-Smart Society is one in which the value of water is recognised and realised to ensure water security, sustainability, and resilience; all available water sources are managed so that water scarcity and pollution are avoided; water and resource loops are largely closed to foster a circular economy and optimal resource efficiency; the water system is resilient against the impact of climate and demographic change; and all relevant stakeholders are engaged in guaranteeing sustainable water governance.

The Water-Smart Society Model

Water Europe has developed a model for a Water-Smart Society to illustrate its key objectives, and the different elements involved in the above paradigm shift as well as their inter-relationships. As presented below, the model consists of one core value, three key objectives that need to be achieved to realise the core value, and five specific innovation concepts that are crucial to realising the objectives. The model indicates how the innovation concepts and key objectives are interrelated, and together generate a 'flying wheel' effect that drives the process towards the Water-Smart Society.

Figure 1. The Water-Smart Society model



Source: Water Europe

One core value

The Value of Water is at the heart of Water Europe's vision for a Water-Smart Society. This core value reflects the centrality of water as a human right and its fundamental role in our society. A multifaceted role that includes enabling all economic activities, underpinning societal functions related to citizen health and well-being, while also representing a source of economic value generated from the extraction and valorisation of raw materials and energy contained in water systems, thereby offering a unique sustainable source to serve a circular economy.

Three key objectives

1. Water Security: safeguarding sustainable access to sufficient quantities of affordable and fit-for-purpose water, in order to preserve the health of the population and ecosystems, foster the socio-economic development of society, and ensure their protection against water-related disasters, such as those resulting from climate change.

2. Water Sustainability: ensuring water infrastructure, management and use that are economically and environmentally sustainable, in a way that meets current ecological, social and economic needs, without compromising the ability to meet these needs in the future.

3. Water Resilience: achieving long-term resilience, so that natural and anthropogenic water systems can withstand unexpected disruptive events, averting serious consequences, such as droughts and floods, while guaranteeing the reliability of the water system.

Five Innovation concepts

1. Circular Water: circular water system that minimises water losses, captures and exploits the value in water, and fosters water security, sustainability and resilience.

2. Multiple Waters: incorporate a wide range of water sources and qualities (groundwater and surface water, rainwater, brackish water, brine, grey water, black water, recycled water) into a water-secure, resilient and sustainable water system.

3. Digital Water: exploit the benefits of the extreme interconnectivity of people, devices and processes, and create capillary networks capable of monitoring the water system, starting at its multiple sources through to the individual end-user, thus generating continuous flows of valuable data for innovative decision-support systems at different governance levels.

4. Inclusive Water: establish a water system whose governance balances the interests of all stakeholders in its design, management and maintenance.

5. Resilient Water: create a resilient and reliable hybrid grey and green water system, designed to withstand severe external and internal shocks – such as climate-change induced floods and droughts – without compromising essential functions.

Transitioning to a Water-Smart Society

In short, Water Europe envisions a significant transformation of the current European water sector. The innovation concepts outlined above, along with measurable objectives and key impact parameters for water security, sustainability and resilience, will drive decision-makers to realise this transition and build new water-smart economies. This will be enabled primarily by innovative governance models, new technologies created within inclusive, open innovation environments, such as innovation-enhancing Water-Oriented Living Labs (WOLLs), and by a transformed and updated water infrastructure serving the Water-Smart Society.

Overall, the Water Europe water vision aims at the implementation of a set of innovations which will result in a 50% reduction in the demand pressure exerted on our groundwater and surface water resources, thereby eliminating water scarcity in Europe.

By 2030, the transition to a Water-Smart Society will be in full swing, driven by visionary front-running industries, cities and rural areas. These will have taken the lead in laying out the migration paths towards the Water-Smart Society of the future. They will have implemented ambitious long-term investment and innovation programmes, as well as real-life WOLL experimental areas. WOLLs will have created a European network of fertile and inclusive innovation ecosystems, where solution developers, researchers, forward-looking water users and water governing bodies will develop the leading solutions of the future. In Water Europe's vision WOLLs will play an important enabling role in driving the transition to the Water-Smart Society. They will boost Europe's competitiveness in the global water market, creating numerous new green jobs in Europe, while making significant contributions towards achieving Europe's Green Deal targets and the UN's Sustainable Development Goal 6 (Clean Water and Sanitation) and other water-related SDGs.

Table of Contents

Abbreviations and acronyms 5

Abstract 5

Executive Summary 6

1. Introduction 8
   - 1.1 Water for life, water for health 6
   - 1.2 Challenges to water availability and quality 7
   - 1.3 Towards clean water and sanitation for all in a Water-Smart Society 7

2. Water-related disease and health threats 10

3. Causes, challenges and opportunities 12

4. Recommendations 14

5. Conclusions 16

6. References 17

Abreviations and acronyms

AMR	Anti-microbial resistance
AOP	Advanced oxidation processes
BAC	Biological activated carbon
BOD	Biochemical oxygen demand
CECs	Contaminants of emerging concern
COD	Chemical oxygen demand
DALYs	Disability-adjusted life years
EPR	Extended Producer Responsibility
EPs	Emerging Pollutants
GAC	Granular activated carbon
IPCC	Intergovernmental Panel on Climate Change
NF	Nanofiltration
PAC	Powdered activated carbon
PFAS	Perfluoroalkyl chemicals
RO	Reverse osmosis
SDGs	Sustainable Development Goals
SEP	Social Engagement Platform
UWWTD	Urban Wastewater Treatment Directive
WASH	Water, sanitation and hygiene
WEFE	Water, energy, food and ecosystem (nexus)
WHO	World Health Organization
WSP	Water Safety Plan
WWAP	World Water Assessment Programme
WWTP	Wastewater Treatment Plant

Abstract

- Water Europe envisions a Water-Smart Society that recognizes and realizes the value of water and its importance for public health. We need to face the multiple challenges that threaten the availability of water and its quality, and have negative consequences for human health and ecosystems. By endorsing the Sustainable Development Goals of the 2030 Agenda, in particular SDG 6, the European Union commits to finding and implementing solutions to the threats posed by the spread of waterborne and water-related diseases, water pollution and water scarcity, which are exacerbated by the current climate crisis. The Zero Pollution Action Plan clearly expresses the need for reducing pollution to levels that are not harmful to human health and ecosystems. With the present White Paper, the Water Europe Working Group on Water & Public Health presents a collective perception of stakeholders from the European water sector on ensuring safe water for all, through;

- an analysis of current water-related health threats;

- an exploration of a set of recommendations for evidence-based water management;

- an examination of policy development to address the water - public-health nexus (WPH).

The Water Europe Working Group on Water & Public Health makes the following five recommendations:

1. The adoption of an ecosystem approach that recognises and ascribes value, including economic value, to the ‘services’ natural ecosystems provide in terms of water filtration and purification and ensures their sustainability through modern management regimes.
2. The integrated management of water resources, connecting the entire water chain, and protecting water from contamination, from household to global levels.
3. The development of a coherent policy framework to protect and value public health, via safe, secure, and accessible water.
4. The implementation of existing technological solutions, including through ad hoc regulation and public and private investment.
5. The engagement and activation of citizens and local communities to co-create solutions, raise awareness, and strengthen socio-political consensus on water policies.

Executive Summary

Water Europe envisions a Water-Smart Society that recognises and realises the value of water and its importance for public health, that deploys innovative and digital water technologies in an environment where water use is reframed within a hybrid grey and green water infrastructure, and in which stakeholders play an important role. To achieve this, we need to meet multiple challenges that threaten the availability of water and its quality, and have negative implications for human health and ecosystems. By endorsing the Sustainable Development Goals of the 2030 Agenda, and in particular SDG 6, 'Ensure availability and sustainable management of water and sanitation for all', the European Union commits to finding and implementing solutions to the threats posed by the spread of waterborne and water-related diseases, water pollution and water scarcity, which are exacerbated by the current climate crisis. The Zero Pollution Action Plan, as part of the European Green Deal, clearly expresses the need to reduce pollution to levels that are not harmful to human health and ecosystems. With the present White Paper, the Water Europe Working Group on Water & Public Health presents a collective perception of stakeholders from the European water sector on ensuring safe water for all, through:

- an analysis of current water-related health threats;
- a set of recommendations for evidence-based water management;
- policy development to address the water & public health nexus.

Water is vital to human health. Humans and all other forms of life need to consume a minimum amount of water for their survival, and access to safe water, sanitation and hygiene is the most basic human need for health and well-being. Moreover, water also plays a central role in many other spheres of human life, which have direct and indirect repercussions on health. Agriculture, fish farming, industrial production and energy generation all require large amounts of water. In addition, water is a fundamental component of ecosystems, on which our health and well-being depend. On 28 July 2022, the UN General Assembly declared access to a clean, healthy and sustainable environment, to be a universal human right, thus stressing the need to make health and the environment our top priorities, and to jointly address these challenges to ensure a common future of economic growth and employment.

Water is however a finite resource A resource that is increasingly stretched by rising demand due to rapid population growth, urbanization, the increasing water needs of the agricultural, industrial and energy sectors, and by the misuse, poor management, over-extraction of groundwater, and the contamination of freshwater supplies. To ensure public health, the major challenges of water scarcity, microbiological threats, and the presence of toxins and polluting residues need to be addressed. To do this, we need first of all a new holistic, integrated and systemic approach, enabling smart water management based on social, environmental and economic sustainability criteria.

The Water Europe Working Group on Water & Public Health makes the following recommendations:

- The adoption of an ecosystem approach which recognises and ascribes value, including economic value, to the 'service' that natural ecosystems provide in terms of water filtration and purification, and ensures their sustainability, through modern management regimes.
- The integrated management of water resources, connecting the entire water chain, and protecting water from contamination, from household to global levels.
- The development of a coherent policy framework to protect and value public health, via safe, secure and accessible water.
- The implementation of existing technological solutions, including through ad hoc regulation and public and private investment.
- The engagement and activation of citizens and local communities to co-create solutions, raise awareness, and strengthen socio-political consensus on water policies.

1. Introduction

1.1 Water for life, water for health

Water is vital to human health. At a very basic level, humans and all other forms of life need to consume a minimum amount of water for their survival. In 2010, the UN General Assembly explicitly recognised the human right to safe drinking water and sanitation.[1] Water has a broad influence on health and well-being, since the quantity and quality of the water supplied are important in determining the health of individuals and entire communities. For many of the world's poor, the inaccessibility to safe water and sanitation remains one of the greatest environmental threats to health. Over 1 billion people globally have no access to safe drinking-water supplies, while 2.6 billion lack adequate sanitation. Diseases related to unsafe water, poor sanitation and low standards of hygiene result in an estimated 1.7 million deaths every year, and antimicrobial resistance (AMR), often transmitted via water pathways, could kill 10 million people annually by 2050.[2] Due to the contamination and the depletion of water resources, about one-third of the world's population live in countries with moderate to high water stress, and problems of water scarcity are increasing. Moreover, water also impacts human life indirectly because of its role in the production of food and energy, and the processing of goods and materials.

Source: Adobestock

Numerous socio-economic impacts of water resources also need to be taken into consideration. Since water is basic to human survival and a key input to almost all production, access to safe water is a condition for the exercise of other human rights and for socially sustainable economic development. Access to running water removes barriers to economic growth for both individuals and society. In fact, when water becomes accessible in developing countries, the productivity of those engaged in collecting it – usually women and children – is freed up. Access to basic water services could possibly save women the equivalent of 77 million working days per year.[3] Water is thus vital to ending extreme poverty and to achieving 'full and productive employment and decent work for all', as articulated in Social Development Goals (SDGs) 1 and 8.

In addition, water is a fundamental component of ecosystems, on which our health and well-being depend. On 28 July 2022, the UN General Assembly declared access to a clean, healthy and sustainable environment, a universal human right, thus stressing the need to make health and the environment our top priorities, and to jointly address these challenges to ensure a common future of economic growth and employment[4].

Lastly, water plays a central role in public health strategies as a powerful monitoring tool. Wastewater surveillance, which has played an important part in the polio-eradication campaign since the late 1930s, has also been successfully used to identify SARS-CoV-2 outbreaks and track new variants. This sentinel system is a promising strategy for modernizing public health surveillance systems and boosting public health preparedness. [5]

In conclusion, water impacts human health and well-being in multiple ways. It is of central importance for drinking and for its sanitary uses, but also in agriculture, industry and the generation of energy, and because of its fundamental role in sustaining the environment. With SDG 6 of the 2030 Agenda for Sustainable Development, the United Nations commits to achieving universal and equitable access to safe water, sanitation and hygiene (WASH) by 2030. Ensuring water in adequate quality and quantity, however, is a goal that cuts across the entire Agenda: it affects all areas of human life. Water is a catalyst for action and progress across all 17 SDGs.

1.2 Challenges to water availability and quality

Water is however a finite resource. A resource that is under growing pressure produced, on the one hand, by rising demand due to rapid population growth, urbanization, and the increasing needs of the agricultural, industrial and energy sectors, and, on the other, by the misuse, poor management and over-extraction of groundwater, and the contamination of freshwater supplies. To ensure public health and achieve the targets set by the SDG 6, water scarcity, microbiological threats, and the presence of toxins and polluting residues are the major challenges to be addressed. The task is all the more pressing in a context of climate change, which exacerbates existing problems and creates new ones. As a consequence, the following challenges are expected to grow in the near future:

- aquatic ecosystem biodiversity loss and degradation;
- impact on human mobility and migration;
- impact on human health, such as transmission of pathogens, reduced food availability, loss of crucial ecosystem services linked to the water cycle;
- changes in the cryosphere (glaciers, snow, permafrost);
- changes in evapotranspiration, precipitation and soil moisture;
- increasingly polluted surface water bodies;
- destocking of pollutants (nitrates, metals) and organic micropollutants (pesticides, cyanobacteria toxin), due to biotic or abiotic metabolization;
- systemic changes in the nature of natural organic matter (NOM) and increase in its concentration;
- intermittent discharges and runoff events caused by more excessive rainfall, leading to supply disruptions or inundations that can facilitate the growth and spread of pathogens.

All these phenomena will affect the treatment and distribution of drinking water and its cost, making more and further treatment necessary. They will also have negative impacts on several economic sectors (fishing, fish farming, agriculture, energy, industrial water, etc.) and people's lives.

1.3 Towards clean water and sanitation for all in a Water-Smart Society

To achieve universal access to drinking water, sanitation and hygiene, a new approach to water management is needed. New technologies, solutions, business and governance models have to contribute to developing a society in which the value of water is recognised and realised, and all available water sources are managed in such a way that water scarcity and water pollution are avoided. In the future Water-Smart Society, water, sanitation and hygiene services must be guaranteed to all, with particular attention to women and girls, who are especially affected by the lack of sanitation. Achieving gender equality in the water sector is vital in view of the sustainable development commitments enshrined in the 2030 Agenda.[6] An in-depth analysis, conducted by the UNESCO World Water Assessment Programme (WWAP) and a dedicated working group, composed of experts from UN agencies and representatives from member states' water agencies, universities and NGOs, has shown that progress towards realising these global commitments is slow. Gender inequalities in the water sector are profound and persist at all levels, seriously affecting international efforts to achieve sustainable development.

In addition, the Water-Smart Society of the future must ensure access to a reliable supply of high-quality water in an environmentally sustainable way. To meet this goal, Water Europe proposes the concept of 'multiple waters for multiple purposes and users', envisioning a future in which different alternative water sources and qualities (surface- and groundwater, rainwater, brackish water, saline water, brines, grey water, black water, recycled water) will be available in our society, and employed for multiple purposes by multiple users. The highest quality water would thus be destined for drinking or food and beverage production, and lower quality water for other purposes (e.g., for industry and irrigation).

This White Paper investigates the role of water in public health, identifying threats, challenges and opportunities within the European context, yet maintaining a global perspective in view of the interconnectedness and the global scale of the issues being addressed: ensuring access to water and sanitation in Europe alone is not sufficient, given that water or sanitation shortages in one part of the world can have global effects. The emergence of resistant bacteria in one world region can seriously impact the entire world population, whilst water shortages can generate diseases or migrations that can have strong impacts on the European Union.

The present paper also recommends measures that need to be adopted by relevant stakeholders, including the co-creation and implementation of solutions at transnational, national and local community levels. Outlining different approaches, strategies, good practices and virtuous examples, its aim is to inspire policy-makers, researchers, technology developers, water service providers and water management authorities to join forces in building a sustainable, robust, resilient and dynamic Water-Smart Society for Europe, while strengthening Europe's contribution to global societal challenges and to making the SDGs a reality.

2. Water-related disease and health threats

According to the World Health Organisation (WHO), 80% of the world's diseases and 50% of the world's infant mortality are related to poor drinking water quality; specifically, these conditions are at the origin of more than 50 diseases.[7] Infectious and parasitic diseases are the major cause of morbidity in developing countries and lead to important outbreaks worldwide. Many water-related diseases result in epidemics with potentially high mortality ratios. In 2016, a large proportion of the overall disease burden, 3.3% of global deaths and 4.6% of global disability-adjusted life years (DALYs), was attributed to quantifiable effects of inadequate WASH. This represents nearly 2 million preventable deaths and 123 million preventable DALYs annually. Children under 5 years of age are disproportionately affected by inadequate WASH (accounting for 13% of all deaths and 12% of all DALYs).

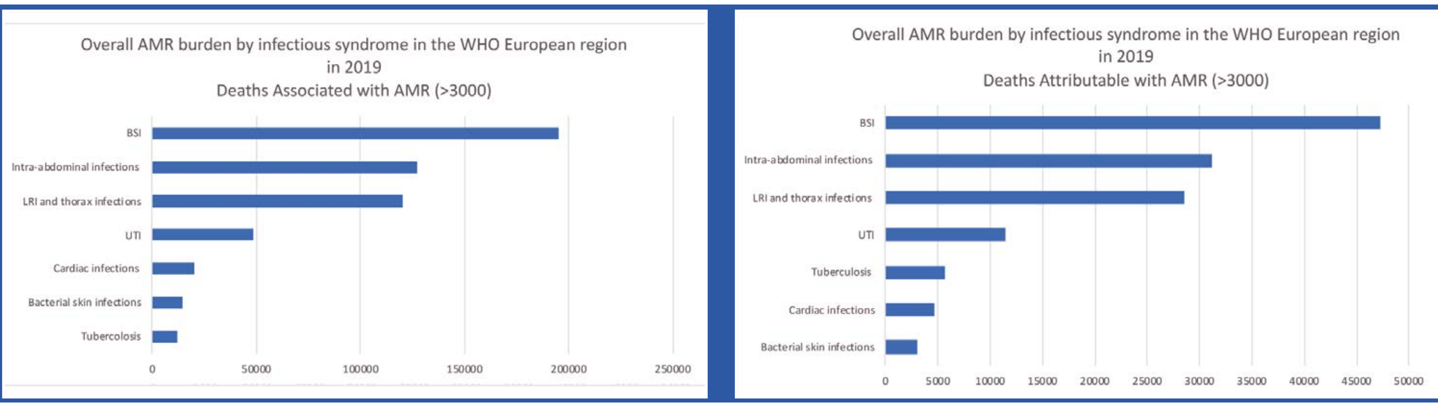


Table 1. Overall AMR burden by infectious syndrome in the WHO European region in 2019. Data are estimates (95% uncertainty interval) and calculated on average.

Infections caused by waterborne pathogens are also reported by WHO in the European region, including viral hepatitis, cholera, typhoid, dysentery, and other diseases that cause diarrhoea. Campylobacteriosis, giardiasis, hepatitis A and shigellosis are the most reported gastrointestinal infectious diseases in the European region. The diseases with the highest number of reported outbreaks are viral gastroenteritis, hepatitis A, *E. coli* diarrhoea, legionellosis, and Enterococci-caused diseases (UTIs, bacteraemia, IE, meningitis, intra-abdominal infections, etc.).[8]

Furthermore, water-supply structures, such as dams and irrigation systems, can provide habitats for snails and mosquitoes that are intermediate hosts of parasites that cause malaria, Japanese encephalitis, schistosomiasis, onchocerciasis and lymphatic filariasis. An additional danger to human health derives from possible production of toxins by certain microorganisms. Indeed, an excess of nutrients resulting from incomplete wastewater treatment can lead to an important proliferation of algae with the consequent eutrophication and toxin production. Algal blooms and cyanobacterial toxins are also of particular concern for drinking water production, due to the potential health hazards associated with the ineffective removal of the toxins in treatment processes.

Apart from these waterborne and water-related diseases, a variety of chemicals and microbial substances that are detected in water, but currently not subject to existing EU water quality regulations, are also potentially hazardous to human health and the environment, and threatening to the quality and safety of water, even in the developed countries of the European region. The impact of contaminants of emerging concern (CECs) on human health and the environment include toxicity and the non-toxic effects of chemicals and biological pollutants (e.g., bacteria, viruses). At present, new concerns are emerging about the long-term effects of chemicals released into the environment (e.g., on the immune and the neurological systems), but also the mixture effects resulting from cumulative exposure to several chemicals. Lastly, the presence of high quantities of antibiotics in wastewater, scattered through ubiquitous compounds found in pharmaceuticals, personal care products, food, industrial and agricultural products, plastics and building materials, may aggravate the antibiotic-resistance problem. Antimicrobial resistance has been identified as one of the most crucial threats to global health[9] and as constituting a future world emergency.[10]

The challenges posed by CECs will be discussed in the next chapter.

3. Causes, challenges and opportunities

It was only in the 19th century that society became aware of the (micro)biological aetiology of many diseases, including communicable (such as waterborne) diseases. The introduction of sewage collection, conveyance and treatment in urban settings (i.e., sanitary engineering) can indeed be seen as one of the most important historical advances in public health. It reduced the probability that wastewaters containing faecal material, and potentially enteric pathogens, would contaminate drinking water sources. This progress was supplemented by the introduction of water disinfection practices (originally chlorination), which further reduced the probability of human exposure to pathogens in drinking water.

Despite the introduction of these technical advances across the world, their implementation has taken place primarily in urban areas in higher-income countries. Raw sewage is still being discharged worldwide, source waters are increasingly polluted, and drinking water treatment is not universally implemented. Furthermore, currently available water technologies might not be able to control newly discovered agents of disease, a situation which is becoming ever more critical since water cycles (from residual to drinking water) are increasingly circular. Lastly, it needs to be borne in mind that the implementation of high-quality sanitation in one part of the world is not sufficient, since the global flow of goods and people means that poor local sanitation and hygiene conditions in one place can have global effects (e.g., the dissemination of emerging or drug-resistant pathogens).

Source: Adobestock

In order to guarantee access to safe water for all, however, several new challenges need to be addressed besides the upgrading of water sewage and treatment systems. The main challenges include the following:

- CECs: synthetic or naturally occurring chemicals or any microorganisms not commonly monitored, with the potential to enter the environment and cause known or suspected adverse ecological and/or human health effects. They comprise pharmaceuticals (endocrine-disrupting compounds, analgesics, antibiotics, hormones), pesticides, industrial chemicals, surfactants, and personal care products, which are consistently found in groundwater, surface water, municipal wastewater, drinking water and food sources.

- Disinfection by-products.

- Microplastics: plastics ranging in size from 0,1 micron to 5 millimetres. They are considered primary when directly released into the environment, as in the case of residuals from washing machines or vehicle tyres wear, and secondary when resulting from the erosion of larger plastic items released into the environment.

- Arsenic and other heavy metals.

- Nitrates and fluoride.

- Perfluoroalkyl chemicals (PFAS).

- Nutrients affecting the biochemical oxygen demand (BOD), whose main sources are domestic wastewater, industrial wastewater (e.g., paper or food processing industries), and agricultural silage effluents and manure.

At present, the effects of CECs on human health and ecosystems are still under study. The long-term (chronic) effects of chemicals (e.g., on immune and neurological systems) and their mixtures on both humans and other species remain largely unknown. Among CECs, microplastics are of particular concern. Questions have been asked about the human health impacts of the exposure to microplastic particles, from the polymers themselves to the monomers, as well as additives used to make the plastic material, adsorbed chemical contaminants and associated biofilms. Recognizing this, WHO is currently assessing the potential risks to human health, considering the exposure from the environment, including exposure via food, water and air.[11]

There is therefore a critical need to fully characterise the effects of cyanotoxins, microplastics and nanoparticles, and to consolidate the list of wider chemical groups impacting microbial resistance (e.g., pharmaceuticals, and chemicals used in biocidal and personal care products). As Water Europe highlighted in its recent White Paper 'Towards a zero-pollution strategy for contaminants of emerging concern in the urban water cycle,'[12] filling knowledge gaps is crucial to achieving a pollutant-free water environment, which is a major component of the European Green Deal's Zero Pollution Action Plan, the EU 2030 Biodiversity Strategy and the EU Urban Agenda.

While it is true that water can be a conduit for many diseases, new opportunities are also emerging related to the monitoring of wastewater. Water-based epidemiology represents a new frontier for public health, since wastewater can also provide epidemiological data and support the development and implementation of public health strategies. This was recently demonstrated during the COVID-19 epidemic, when many countries – including the EU, as harmonized under its Sewage Sentinel System – used direct detection and quantification of SARS-COV2 viral RNA in raw wastewater as a rapid and cost-effective indicator of virus levels in populations. Such analysis is of great relevance since it does not rely on the health-care-seeking behaviour of individuals, and thus provides a faster and more efficient indicator than does population testing. It allows for faster responses, and could also be used to predict any re-emergence of new waves, once human testing is no longer used.

Wastewater treatment plant – source AdobeStock

After having played an important part in the polio-eradication campaign[13], wastewater-based surveillance has also recently become the focus of attention for the identification of future threats and trends related to emerging pathogens and CECs for public health. For example, there is strong interest in using wastewater-based surveillance to monitor trends and dynamics of AMR and to develop suitable intervention and management strategies; clear trends can indeed be inferred based on the global sewage surveillance projects carried out so far. This tool can be successfully used not only to detect biological pollutants, but also to provide non-intrusive and anonymized information on other health issues and population-level drug (licit or illicit) consumption behaviours. In this context, microbial monitoring during the whole water cycle becomes critical to ensure safe water free of pathogens. Both the direct detection of certain pathogens and the detection of indicator microorganisms are complementary tools for this purpose. Detecting bacterial indicators such as *E. coli* or *Enterococcus* has become part and parcel of water management systems since the last century; however, viruses resist water treatment processes better than bacteria, so specific indicators, such as somatic coliphages, are also needed.

Microbiological minimum parameters across EU water-related policies should at least cover the following:

- *E. Coli*
- Enterococci
- Legionella Pneumophila
- Cryptosporidium
- SARS-CoV-2 virus and its variants
- poliovirus
- influenza virus

4. Recommendations

The 21st century health issues highlight the need for considering a holistic approach that takes into account the interconnectedness of the problems being faced. This is particularly true in the case of water, a crucial resource for human health and ecosystems, but also for food and energy production. Only by bearing in mind the water-energy-food-ecosystem (WEFE) nexus, can the challenges be turned into opportunities for Europe to develop new technologies, solutions, business and governance models to ensure public health and a Water-Smart Society. For this reason, taking care of human health requires taking care of the health of ecosystems, which provide water-replenishing and -purifying services essential for human well-being. However, the sustainability of many of these ecosystems has been impacted by urban development and land-use changes. These changes concern the elimination of marshes and wetlands, the diversion of surface water or alteration of flows, the increased exploitation of underground aquifers, and water contamination by waste and discharges from industry and transport, and by household and human waste.

A further illustration of how different disciplines and expertise silos must work together for a common cause is the issue of the natural phenomenon of antimicrobial resistance, which is worsened by anthropogenic impacts, such as use and misuse of antimicrobial agents (antibiotics, antifungals, antivirals, antiparasitics), insufficient sanitation and poor waste management. This contributes to the emergence and spread of AMR in wastewater, fresh and marine waters, drinking water, soils, and in wildlife. To tackle the AMR issue, a One-Health approach is necessary, involving clinical, veterinarian and environmental aspects. The reduced use of antimicrobials alone will not be sufficient to control AMR; this effort will need to be supported by improved sanitation, waste management and increased access to clean water. There is a need for a paradigm shift from conventional disinfection, with the primary aim of inactivating pathogens, to effective damage to the DNA and resistance genes that could still be present after microbial inactivation.

In light of the above-described need for a nexus approach, this White Paper would further recommend the measures, solutions and intervention methods presented below. It is worth stressing that they are all interlinked and require joint planning, if we are to meet the daunting global challenges related to water and public health and, in this way, achieve SDG 6.

a) An ecosystem approach

Natural ecosystems have intricate and resilient mechanisms which filter and replenish freshwater resources and sustain marine environments. Although human technologies may enhance or replicate these mechanisms in some settings, protection of the natural watershed is also critical. An 'ecosystem approach' recognises and ascribes value, including economic value, to the 'services' natural ecosystems provide in terms of water filtration and purification, and ensures their sustainability, through modern management regimes.

An example of an ecosystem approach is the use of mixed methods (i.e., a scientific-based ecosystem services assessment and interviews with local communities) to develop an integrated understanding of the role of blue-green urban spaces in delivering multiple benefits (Juntti et al., 2021). Findings supported the development and implementation of a blue-green network within the metropolitan area of Belo Horizonte, Brazil, through their adoption into municipal law by three municipalities.[14]

b) Integrated water resource management

A watershed has multiple users with different needs and influences on water, so that an integrated management approach is essential to the sustainability of water resources. Upstream uses of water impact the possibility of downstream users meeting their needs. Land use, agricultural patterns, and industrial development all affect water resources. A wide range of sectors, for example, agriculture, energy, industry, fisheries, tourism and local government, must all plan and coordinate strategies on the full range of developments that affect ecosystems, natural hydrology and water consumption, with reference to the expert advice and guidance of the health and environmental sectors.

Moreover, integrated water management also means protecting water from contamination from household to global levels. The careful disposal of waste, preventing water source contamination, and the protection of health from contaminated water sources are vital principles, which need to be adopted from the personal to the international level. They range from simple hygiene practices, such as good handwashing and the safe production and storage of household water resources, local and municipal sanitation, waste disposal systems, up to global strategies and conventions aimed at protecting both fresh and marine water sources from transboundary waste, unsustainable resource use and contamination.

The development and implementation of water quality standards, the monitoring of water quality and of water-related disease indicators, such as *E. Coli* as a bacterial indicator, somatic coliphages as a viral indicator, and spores of clostridia, as a parasite indicator, are all appropriate for the surveillance and control of water resources.

Integrated water resource management underpins the use of nature-based solutions (NBS) to manage urban stormwater runoff. In contrast to the use of piped systems, which address flow only through direct discharge to receiving waters, the use of NBS (e.g., rain gardens, ponds, and wetlands) provide an opportunity to address stormwater management in relation to water quantity (infiltration/detention), water quality (pollutant removal/degradation) and societal (health and well-being benefits) objectives (Woods Ballard et al., 2015).[15]

c) A coherent policy framework to protect and value public health via safe, secure and accessible water

All water-related policies need to be interrelated and coherent, in a manner that information is easily accessible to all water actors, from utilities, to distributors, end-users, to those responsible for water treatment, wastewater treatment and water reuse. Policies need to have a clear and defined set of microbiological and chemical parameters, also encompassing CECs. The lack of clear requirements unfortunately leads to a lack of action. The polluter-pays principle has to be applied even if the polluter is the same citizen. Public health and cost considerations should prevail as guiding principles. In this context, one of the options under consideration by the European Commission is the Extended Producer Responsibility (EPR) approach, which extends the producer's responsibility for a product to the post-consumer stage of its life-cycle. EPR seeks to integrate signals related to the environmental characteristics of products and production processes throughout the product chain, and could have important applications in many sectors closely associated with water pollution, such as pharmaceuticals.

d) Technological solutions

All technological solutions have advantages and disadvantages, which is why they must be evaluated according to the various application contexts, the chemical-physical characteristic of the contaminants and of the water to be treated, the multiplicity of contaminants and their concentration, and all the other factors which can lead to interactions that can reduce the efficiency of the processes themselves. Technical analysis must be supported by a preventive risks analysis and by economic and environmental analysis. Depending on the use of the wastewater and the quality of the water one wants to achieve, different levels of integrated treatment will be required: primary, secondary, tertiary or quaternary.

Currently available solutions

To substantially influence the quality of surface water by reducing biodegradable pollution in wastewater – such as high levels of BOD – one needs to combine the available primary mechanical treatments with secondary treatments (biological wastewater treatment). At the same time, it is important to connect as many people as possible to wastewater treatment systems, even by means of decentralised systems in rural areas. After secondary treatment, wastewater can still contain high levels of dyes, surfactants, CECs, drugs, hormones, nutrients such as nitrogen and phosphorus, and other substances that are difficult to degrade. To eliminate these pollutants, one can apply tertiary treatments, also known as 'effluent polishing'. These treatments include both biological (enhanced biological phosphorus removal, nitrification and denitrification), and physical/chemical removal processes for phosphorus and nitrogen. Ozone oxidation or advanced oxidation processes are also often used to remove odours, unwanted colouring substances, flavours and recalcitrant chemical oxygen demand (COD) and BOD. For the removal of arsenic from drinking water, ferric oxide media are used, whilst solid activated alumina can be used to remove fluoride. The media can also adsorb lead, antimony, chromate, cadmium, molybdenum, vanadium and selenium. A quaternary treatment might be required to remove CECs present in water at trace levels, and which can be hazardous to human health and/or the environment. Many full-scale processes for the removal of CECs have been studied in recent decades. The most studied are the following:

- separation by pressurized membrane: nanofiltration (NF) and reverse osmosis (RO);
- adsorption on activated carbon, either in granular (granular activated carbon, GAC) or powdered form or exchange resins (powdered activated carbon, PAC);
- oxidation by ozone or by advanced oxidation processes (AOP);
- oxidation by solar AOPs and solar photochemical processes.

Limitations of current technologies and possible solutions

While the above processes are effective against a range of pollutants, including microbial contamination, and have specific advantages, they also have some weaknesses and drawbacks. Membrane separation systems involve the treatment or disposal of concentrates, and typically require additional pre-treatment systems to reduce fouling and scaling. NF and especially RO not only remove EPs but also salts; if this is not desirable, RO systems need to be coupled with remineralisation systems, particularly in drinking water treatment. The operating costs for large water flows are high due to energy consumption associated with pumping. The EP adsorption capacity of activated carbon can decrease in the presence of other organic compounds; moreover, the use of GAC involves the need for regeneration or replacement, with associated disposal. Adsorption processes may also require a disinfection process to enable water reuse or, if PAC is applied, a post-filtration to remove carbon particles. AOP can lead to the creation of unmeasurable or unmeasured by-products, and for this reason, besides toxicity monitoring, their combination with adsorption systems (such as activated carbon) or membrane systems is often recommended.

Solutions often involve a combination of several technologies and a multi-barrier approach offers a possibility to maximise opportunities for the removal of a wide range of CECs. One of the effective combinations involves ozone and biological activated carbon (BAC), or ozone and a biological activated filter (BAF), which result in the simultaneous adsorption and biodegradation of organic compounds. The increase in molecules' biodegradability can reduce the degree of absorption and facilitate their biodegradation by the dark mass adhered to the activated carbons. This process reduces the competition of organic matter with other substances to be absorbed by the activated carbons, and can prolong the useful life of the activated carbon.

Many drinking water plants and the majority of wastewater treatment plants were not designed for the removal of CECs or other pharmaceutical compounds. The installations in Switzerland and Germany demonstrate that ozonation and adsorption on activated carbon, in addition to secondary treatment, are effective and are also economically viable.[16]

New challenges posed by disinfection by-products management

The recent regulatory change (Directive EU 2020/2184) regarding the quality of water intended for human consumption added further disinfection by-product limits. Chemical disinfectants are used mostly for secondary disinfection (to maintain the disinfection residual throughout the pipeline to consumers). Chlorine-based products are the most widely used for their effectiveness and the knowledge acquired over many years of use. Other biocides are being studied, but their application will require time and testing, since the impact of their use, on a large scale, over many years, in large distribution networks, is unknown.

It is critical to strike a proper balance between the need to control pathogens to avoid acute risks to human health, and to control by-product formation to avoid chronic danger to users. To date, bulk sodium hypochlorite is one of the most widely used products in the EU. It is subject to various factors (like storage time, temperature and impurities) that can promote the presence and creation of by-products. There are solutions capable of producing the active chemicals on-site and creating fewer chlorates (in comparison with bulk sodium hypochlorite), based on natural precursors such as water and salt (on-site low chlorate hypochlorite generation). Reduction of by-product production can be achieved by combining different technologies, such as ozone + BAF. These technologies act on organic substances and their reaction with oxidizing agents. If the levels of trihalomethanes or halo acetic acids are high, the problem can be solved by switching to chlorine dioxide, acting on organic load, and making multiple injection points.

The use of photochemical AOPs has been widely investigated in recent decades, with very promising results for both water disinfection and decontamination, in a search for treatments that are low-cost, environmentally-friendly, use renewable energy such as naturalsolar radiation and reduce the carbon footprint. The interest on this process is based on the high oxidant capability and non-selectivity of the process, which allows the oxidation of a wide range of organic compounds (eventually reaching the complete mineralization into carbon dioxide, water and inorganic ions), and the effective inactivation of a wide spectrum of waterborne microorganisms, without the generation of disinfection by-products. The most explored sunlight-based AOPs are the heterogeneous photocatalysis with semiconductors (mainly TiO2) and the homogeneous photocatalysis with iron salts, the so-called photo-Fenton process.[17] Moreover, there is a growing recent interest in solar-based water treatments that use oxidative agents (at very low concentrations), including hydrogen peroxide (H2O2), persulfate, peroxymonosulfate, free chlorine or peracetic acid. Their advantage is that they do not require additional pre- or post-treatment of the water, while generally maintaining a high capability for water purification: simultaneous disinfection and decontamination, residual oxidising effect (preventing microbial prost-treatment regrowth), absence of toxicity, minimised costs (compared to aforementioned solar AOPs). In particular, the combination of free chlorine with sunlight has recently proven to significantly increase the capability of this oxidant against the removal of chemical organic compounds in natural waters.[18]

In conclusion, research, innovation and continuous experimentation are needed to find technological solutions to the urgent challenges of the water sector. But reflections on the development of new technological solutions must also take into account the obstacles posed by long authorisation procedures. According to a recent study,[19] in the water sector the adoption of a new technology that is driven purely by its value proposition typically takes around 14 years. In contrast, for the adoption of a new technology that is driven by a crisis or market need, such as a new piece of legislation or an urgent health or environmental issue, the timeline can be half this, at just under 7 years. The passage of ad hoc legislation to facilitate the adoption of new technologies is therefore crucial, so as to ensure that the time taken in the authorisation procedures does not exceed that needed for the development of new technology. This would avoid situations in which the implementation of technologies is finally authorised at a time when they are already obsolete.

e) Socio-political solutions

Long-term environmental and health policies require continuity if subsequent actions are to bear fruit. Continuity is the result of socio-political consensus, which in turn derives from a transparent and attractive approach to the process of social communication, creation of informed concern, and a broad societal acceptance of co-creation and implementation. The actions described here have been implemented in real-life situations and consider the need for extremely low-cost, economic but practical actions.

To ensure the viability of long-term awareness creation, policy co-creation and political continuity, supranational health and water strategies must be implemented and/or supported by regional and local stakeholders. The local stakeholders include the public sector, private sector, research sector, citizens, NGOs and representatives of socio-cultural entities, who would be involved at all stages of policy creation and the implementation process of resulting actions. A model composed of political, educational, economic, environmental, and social systems is known as the Quintuple Helix. The incorporation of and dissemination to local schools, colleges and universities is also of great significance, as this is a general approach to youth and women groups.

It is in this context that the European Commission has drawn up the so-called 'Renaissance' approach, proposing the 'TAP' procedure, the components of which are detailed below.

- T– The Technologies to address the challenges raised by SDG 6, and indeed by most other Sustainable Development Goals, already exist. The purpose of Renaissance is not only to analyse but to communicate with society to promote an open, bi-directional, effective mechanism of solution exchange, trans-regional collaboration, and the all-important capacity to ensure full policy completion.

- A – International, regional, and local Awareness is promoted by giving prominence to scientific imagery accompanied by the emotional capacity of culture through Art. Objectives must become mainstream. Science must learn to interact with social and political communicators, whilst cultural and political stakeholders must seek interaction with specialised experts. Complex scientific data must be translated into a language which can attract the attention and encourage the participation of the hitherto unaware laymen, politicians, and other social actors with whom the scientific community all too often find it difficult to establish a mutually beneficial dialogue.

- P – The collection of data will serve for nothing if it does not result in the identification of necessary solutions and lead directly to Policies supported by the People and translated into reality by Practitioners in the field.

By working in close collaboration with municipalities, supranational ambitions can be translated into regional and local facts. The employment of the co-creation and public implementation system can be based, for example, on the establishment of 'Local Water Forums' in cities, towns and villages. A Local Water Forum is a group of volunteers from a municipality, who meet with members of the local council, local and regional health authorities, and the local water utility. They are responsible for the co-creation and implementation of water-based health policies, where citizen volunteers become the overall non-technical supervisors of the resulting plan, the spokespeople who will be responsible for informing both the local community and members of other Local Water Forums from around the world of their experiences, whilst receiving support and training from local entities and members of the professional sectors.

In this way, supranational necessity based on international data, is converted into local policy, supported by representatives of the Quintuple Helix (public sector, private sector, industrial sector, research sector, citizens and cultural entities) at a local level. The social engagement movement suggested must clearly demonstrate to all potential stakeholders what they will gain from becoming involved. This includes their joining a worldwide network and a truly global initiative, based on a shared vision for future advances, the opportunity to obtain a more integrated, inclusive picture of the causes and effects of water-based health issues, the promotion of new local policies within an inclusive decision-making process of cooperation that will increase local support for solutions and measures, access to international technical support from scientists and technicians, and the opportunity to attract international publicity of their progress.

Sustainable cross-sectoral collaboration, the promotion of local solutions for global problems, the transformation of knowledge into action, and the translation of complex data into simple and accessible knowledge will not only engage and activate the citizens, it will also be an important step in enabling stakeholders to be better able to mitigate the effects of past mistakes. Programmes such as the GEMS/Water approach, initiated by the JRC of the European Commission, the World Water Quality Alliance of the United Nations Environment Programme, or the Water and Climate Coalition of the World Meteorological Organisation, are presently demonstrating the practicability, the capacity and the benefits of creating highly motivated citizen scientists, who undertake long-term observation and monitoring within their local communities, whilst being fully involved in the transition of such data into practical public measures. There exists a need for engaged citizen scientists who, before undertaking any observation, monitoring or data collection, will have been involved from a socio-political perspective. This will provide far less sceptical and far more enthusiastic citizen-science volunteers, who will contribute to the health monitoring initiatives over a longer time-period in a more effective way.

An example of an active citizen science programme is provided by Thames 21, a UK-based rivers trust which engages with >7000 citizen scientists every year to carry out practical river improvements and environmental monitoring. Monitoring data collected are used to inform discussions with, for example, river basin management planning committees in which the trust is a partner.[20]

5. Conclusions

Water has multiple impacts on public health because it is central to widely diverse areas of human life. Consequently, the solutions deployed must also be multiple and diverse, as well as mutually synergetic. As the previous chapter shows, many solutions already exist, but are not implemented, or not sufficiently nor systemically. This is particularly true in the case of many problem-solving technologies. The reasons for the lack of implementation include the absence of regulatory obligations, budgetary constraints, and the lack of an integrated approach to water policy and management.

Updated regulation and financial resources needed

Support for research to develop increasingly sustainable solutions remains important, but action needs also to be taken on the regulatory issue, and in providing all actors with adequate financial resources. Data and knowledge must be turned into action. Local, national and European legislation should simplify, harmonise and accelerate the diffusion of technological solutions. The recent proposal by the European Commission on the recast of the Urban Wastewater Treatment Directive (UWWTD) will introduce regulatory obligations on removing and/or monitoring some CECs in urban wastewater treatment. To date, however, European legislation still requires lengthy and complex procedures for the adoption of new technologies and the evaluation of alternative methods. As a result, innovative technological solutions require additional funding to be approved at national and EU level. It is thus necessary to advance government investment and to promote sustainable financing either through public funds or changes in tariff policies, as has been done in some countries to encourage renewable energies. Systems of incentives and disincentives, investments, ad hoc pricing systems and taxation are key to developing sustainable water management, thereby ensuring quality water and greater public welfare. Rethinking the tariff policies of some European countries could in fact encourage water conservation and its more careful use. Significant investments in ensuring quality water, on the other hand, could reduce health expenditure, leading in the medium and long term to resource savings. In this context, an interesting instrument, currently under consideration by the European Commission, is the Extended Product Responsibility, an environmental policy approach aimed at shifting responsibility (physically and/or economically; fully or partially) upstream toward the producer, and at providing incentives to producers to take into account environmental considerations when designing their products.

Water Europe
Technology & Innovation

For a contextualised approach: the case of Water Safety Plans

What is essential, above all, is a change of vision and the involvement of all interested parties. A holistic perspective is needed, allowing for the identification of contextualised solutions within a particular ecosystem, through the timely analysis of risks and environmental components. Only by embracing a new analytical paradigm that includes the study of the exposome, that is, a detailed map of all the environmental components to which an individual is exposed during his or her lifetime, will it be possible to ensure public health. In 2004, the WHO Guidelines for Drinking Water Quality recommended that water suppliers develop and implement Water Safety Plans[21] (WSPs) in order to systematically assess and manage risks. With relatively modest efforts, the WSP approach can bring tangible improvements in water quality and availability for all users. By providing step-by-step guidance for all WSP stakeholders, as well as best-practice examples from a broad range of countries and contexts, WHO's 'A guide to equitable water safety planning: Ensuring no one is left behind' provides a practical tool to help achieve safe water for all.[22, 23] The successful development and implementation of WSPs offers many benefits that are common to all drinking water systems, as well as some that are unique to each system. The main implementation benefit is improved safety and quality of drinking water. To achieve this goal, WSPs provide a framework for risk reduction, the prevention of hazards, and a better response to emergencies, thus improving public health, but also ensuring better watershed management and resilience to climate impacts. Lastly, it is important that this and other contextualised approaches also consider gender diversity and disability in the design of sanitation and disinfection services, especially in developing countries.

Uniform, interchangeable data

All water-related policies need to be interrelated, in such a way that information is easily accessible to all water stakeholders, both professional and non-professional. Policies must have a clear and defined set of microbiological and chemical parameters, as well as encompassing CECs. As explained above, policies must provide for microbial monitoring during the whole water cycle, and must relate to the regulations concerning the clinical and veterinary aspects. Important steps still need to be taken to develop effective data collection and interchange systems. The challenge is to make water data systems responsive to the information needs of decision-makers, so as to enable evidence-based decision-making and a fair and transparent allocation of resources.

Participation, consultation and engagement

Ensuring access to clean water and health also requires the involvement of all stakeholders, including end-users. Sanitation and hygiene promotion must accompany the infrastructural investments, so that their potential benefits are fully realised. Technological solutions alone cannot effectively meet the challenges of the water sector: one also needs to undertake training and awareness-raising actions for citizens, co-created with and by citizens, starting with the young. To structurally solve problems related to water and public health, best practices must be disseminated and replicated, by involving all society at a local and sub-national level, thereby creating widespread trust, ownership, responsibility and leadership. The objective is to train and support citizens and institutions to become aware of the value of water, to work on the reduction of consumption and pollution of water and on water reuse, and willing to invest time and money in the protection of society as a whole. In this context, strong attention should be directed at highlighting the interconnections among water, health and human capital. For this reason, it will be crucial to develop trainings, vocational education, and lifelong learning, in order to hone the skills of the workforce and keep up with technological development, and to incorporate systems thinking as an overarching approach for a better readiness and preparedness. Water Europe actively commits itself to this effort through its Working Group on Human Capital.

An inspiring example in this context is the model proposed by the Social Engagement Platform (SEP) of the World Water Quality Alliance. The objective is to promote transparent, multi-stakeholder processes for water management leading to a broad awareness of global and local water issues. Complex systems are translated to simple language so that they can be understood by everyone. Data are translated into knowledge, and knowledge into simple, realistic, and economically modest action, implemented through theimplementation of the Quintuple Helix at a local level. This is an example of multi-actor engagement, knowledge sharing, production and capital generation that engages members of society.

Lastly, the 'Innovation development environments' also offer interesting case studies of community participation, and are currently being evaluated by Water Europe. In particular, the Freshwater Competence Centre[24] (FWCC), and the case of the Belgian city of Mechelen merit mention. FWCC is supporting the digital and green transition via a public–private partnership. FWCC gathers the highest competence in hydrological and geospatial research, development, and infrastructure in Finland. FWCC, formed by the University of Turku, University of Oulu, the Finnish Environment Institute, Aalto University, University of Easter Finland, and the Finnish Geospatial Research Institute, as well as several private companies and third sectors, is also very active in the field of education, and has developed an open platform to exchange data with citizens able to monitor data about environment restoration.

Mechelen is a city located near the water. In this open-air public laboratory, ways to reintroduce water back into the city are discussed and tested, following its closure in the past. The river Dyle flows through the city, creating a corridor between the two surrounding nature reserves in the hinterland. Throughout the centuries, the course of this tidal river has been altered for various purposes. Today, the river presents both opportunities and challenges. The goal of Mechelen is to create a more resilient city and hinterland by bringing water back into the city. As part of this effort, the city has already created spaces for social gatherings, organized events to attract visitors and encourage them to rediscover the city, and implemented urban makeovers focusing on social infrastructures. Additionally, the city has collaborated with its citizens to gain support and raise awareness about the restructuring of the city's canals, which were previously often privately owned. Therefore, expanding participation in decision-making is key to building a Water-Smart Society."

Ensuring the provision of water in the right quantity and of the right quality to guarantee public health in an environmentally, socially and economically sustainable way represents a cross-cutting challenge. It requires a shift towards a multi-level and polycentric form of water governance, and the active involvement of civil society, the private sector and other stakeholders, in an open and transparent process from an early stage. Water policies require strategic planning, implementation at different jurisdictional levels, and the taking into account of additional cross-sectoral policies. Adequate coordination mechanisms and meaningful collaboration across all jurisdictional levels are essential, if the current lack of implementation of existing technologies and capacity gaps are to be overcome. Effective communication between jurisdictional levels and different sectors is fundamental for stakeholder capacity building, and could also promote a greater acceptance of future development in water policy and emerging water challenges, and a stronger commitment by all actors to their own role and responsibilities in the process. Water Europe is ready to play its part in achieving SDG 6 and other interconnected SDGs, which are an integral part of its Water Vision and of building a Water-Smart Societies.

References

1. World Health Organization **2019**: Safer water, better health. **2019** update.
2. Antimicrobial Resistance Collaborators, The burden of bacterial antimicrobial resistance in the WHO European region in 2019: a cross-country systematic analysis, The Lancet v.7, 11, E897-E913, **2022**; https://doi.org/10.1016/S2468-2667(22)00225-0.
3. https://washmatters.wateraid.org/sites/g/files/jkxoof256/files/mission-critique-investir-dans-leau-lassainissement-et-lhygine-pour-une-reprise-conomique-saine-et-respectueuse-de-lenvironnement.pdf,
4. WHO, UNICEF: Progress on Drinking Water, Sanitation and Hygiene.
5. https://www.nature.com/articles/s41591-022-01940-x.
6. UNESCO, Water and Gender; https://en.unesco.org/wwap/water-gender.
7. Lin L, Yang H and Xu X, Effects of Water Pollution on Human Health and Disease Heterogeneity: A Review. Front. Environ. Sci., 10:880246, **2022**; https://doi.org/10.3389/fenvs.2022.880246.
8. World Health Organization **2016**: The situation of water-related infectious diseases in the pan-European region; https://apps.who.int/iris/handle/10665/329534.
9. Antimicrobial Resistance Collaborators, The burden of bacterial antimicrobial resistance in the WHO European region in 2019: a cross-country systematic analysis, The Lancet v.7, 11, E897-E913, **2022**; https://doi.org/10.1016/S2468-2667(22)00225-0.
10. Statement of WHO chief Tedros Adhanom Ghebreyesus, 18 June **2019**.
11. World Health Organization **2022**: Dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health.
12. https://watereurope.eu/wp-content/uploads/White-Paper-Zero-Pollution_online.pdf.
13. Duintjer Tebbens, R. J. et al. Food Environ. Virol. 9, 361–382 (**2017**).
14. EM Juntti, H Costa and Nascimento (2021) Urban environmental quality and wellbeing in the context of incomplete urbanisation in Brazil: Integrating directly experienced ecosystem services into planning. Progress in Planning **143, 100433, ISSN 0305-9006**. https://doi.org/10.1016/j.progress.2019.04.003
15. Woods Ballard, B, Wilson, S, Udale-Clarke, H, Illman, S, Scott, T, Ashley, R, Kellagher, R (**2015**) The CIRIA SUDS manual SBN: 978-0-86017-759-3. https://www.ciria.org/ItemDetail?iProductCode=C753F&Category=FREEPUBS.
16. Antonelli M., Benzoni S., Bergna G., Bernardi M., Bertanza G., Cantoni B., Delli Compagni R., Gugliandolo M.C., Malpei F., Mezzanotte V., Pannuzzo B., Porro E. 2020. Contaminazione e rimozione di microinquinanti emergenti in acque reflue e in acque destinate al consumo umano. In: GdL-MIE. Inquinanti Emergenti. A cura di: Tartari G., Bergna G., Lietti M., Rizzo A., Lazzari F. e Brioschi C. Lombardy Energy Cleantech Cluster, Milano: page **135-138**; https://hdl.handle.net/11311/1158590.
17. S. Malato, P. Fernández-Ibáñez, M.I. Maldonado, J. Blanco, W. Gernjak, Decontamination and disinfection of water by solar photocatalysis: recent overview and trends, Catal. Today. 147 (**2009**) **1–59**; https://doi.org/10.1016/j.cattod.2009.06.018.
18. Isaac Sánchez-Montes, Irene Salmerón, José M. Aquino, María Inmaculada Polo-López, Sixto Malato, Isabel Oller. Solar-driven free chlorine advanced oxidation process for simultaneous removal of microcontaminants and microorganisms in natural water at pilot-scale. Chemosphere **288** (**2022**) **132493**.
19. O'Callaghan et al., Analysis of adoption rates for Needs Driven versus Value Driven innovation water technologies, Water Environment Research **91(2):144-156**.
20. Thames21.org.uk.
21. World Health organization, Water Sanitation and Health, https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health/water-safety-and-quality/water-safety-planning/water-safety-planning-training-videos.
22. World Health Organization, A guide to equitable water safety planning: Ensuring no one is left behind, https://www.who.int/publications/i/item/9789241515313.
23. The International Water Association, Water Safety Planning to improve public health, water security and climate resilience, https://wsportal.org/wp-content/uploads/sites/3/2021/05/WSP_inclusion_briefing_web.pdf.
24. https://www.freshwatercompetencecentre.com/

Colophon

Name, company/organisation

Editor in Chief: Andrea Rubini (Water Europe)

Authors: Richard Elelman, Eurecat (Spain) ● Cristian Carboni, Industrie De Nora (Italy) ● Claudia Topalli, Idexx (Belgium), ● Irina Calancea, Veolia (France) ● Patrizia Brigidi, University of Bologna (Italy) ● Maria Rowinski, A.O. SS. Antonio e Biagio e Cesare Arrigo di Alessandria (Italy) ● Barth F. Smets, University of Denmark (Denmark) ● Julia Martin, Bluephage (Spain) ● Naomi Timmer, H2O-People B.V. (Netherlands) ● Enric Queralt, Bluephage (Spain) ● Loich Charpentier, Water Europe (Belgium) ● Tone Merete Muthanna, Norwegian University of Science and Technology (Norway) ● Gaia Zanzi (Water Europe) ● Albert Chen, University of Exeter (UK) ● Montserrat Batlle, Adasa sistemas (Spain) ● Frederic Béen, KWR Water Research Institute (Netherlands) ● Marta Betti, A.O. SS. Antonio e Biagio e Cesare Arrigo di Alessandria (Italy) ● Peter Rübig, sme.group (Austria) ● Abhilash Venkateshaiahy, Eden Tech (France) ● Fazel Abdolahpur Monikh, University of Eastern Finland (Finland) ● Elif Tezcan Istanbul Water and Sewerage administration (Turkey) ● Lian Lundy, Luleå University of Technology (Sweden) ● Sara Eeman, Aveco de Bondt (The Netherlands) ● George Suciu, BEIA Consult International (Romania) ● Ilari Aho, Uponor Corporation (Finland) ● Leonard Osté, Deltares (The Netherlands) ● Alexandra Campbell-Ferrari, Center for Water Security and Cooperation (United States) ● Mehmet Dilaver, Tubitak Marmara Research Center (Turkey) ● Pawel Krzeminski, Norwegian Institute for Water Research (Norway) ● Oriane Marchal, France Water Team Cluster (France) ● Isabel Oller Alberola, Plataforma Solar de Almeria-CIEMAT (Spain) ● Raquel Queiros, International Iberian Nanotechnology Laboratory (Portugal) ● Mohamed Elzarei, Haleon (Belgium) ● Inmaculada Polo Lopez, Plataforma Solar de Almeria-CIEMAT (Spain) ● Ece Sagir Kurt, Istanbul Water And Sewerage Administration (Turkey) ● Nigar Eyit, Istanbul Water And Sewerage Administration (Turkey) ● Paula Malheiro, Aguas e Energia do Porto, E.M. (Portugal) ● Eleonora Marton, UnionCamere Del Veneto (Italy)

Layout and design: Ana de León (Water Europe); Andrea Rubini (Water Europe); Ilaria Andreozzi, University of Bologna (Italy) and; Marín Asociados

Copywriting: Richard Elelman, Eurecat (Spain) ● Viola Ducati (Italy) ● Cristian Carboni, Industrie De Nora (Italy) ● Claudia Topalli Idexx (Belgium).

Citation: Water Europe, The role of water in the issue of public health. Brussels

ISBN: 9789464003178

This white paper has been written to stimulate discussion on ensuring safe water for all. The paper does not reflect any formal standpoints of the authors or the organizations where they work.

Water Europe
Technology & Innovation

Water Europe
Technology & Innovation

Water Europe

Technology & Innovation

THE ROLE OF WATER IN THE ISSUE OF PUBLIC HEALTH

WATER EUROPE – B. AUGUST REYERS 80, 1030 – BRUSSELS, BELGIUM
WWW.WATEREUROPE.EU - INFO@WATEREUROPE.EU