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Joint Transnational Bathing Water Strategy

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Executive summary

With warmer summers and more frequent heatwaves, urban bathing waters are becoming increasingly popular, particularly among families with children. While bathing offers multiple benefits for physical and mental health, poorly managed urban bathing sites may pose a risk to health.

Pressures affecting urban bathing waters include treated or untreated sewage discharge, run-off from paved surfaces and faecal contamination from animals, introducing pathogens or potentially harmful chemicals. Climate change further exacerbates these challenges: extreme weather event, especially flash floods increase run-off and may lead to combined sewage overflow, while warming water temperatures give rise to the proliferation of autochthonous microorganisms, such as cyanobacteria and vibrios that may pose a risk to bathers' health.

The European Union (EU) directive 2006/7/EC concerning the quality of bathing waters is the basis of national legislation in member states. However, the current legislative framework leaves significant gaps. Risk-based approach is only tangentially incorporated. Monitoring requirements only address faecal pollution, disregarding other potential hazards and monitoring frequency is insufficient for the reliable characterisation of water quality. Although risk-based approach is part of the legislative framework - in the form of bathing water profiles, it does not drive monitoring or management efforts. National legislations often prescribe additional requirements. Artificial bathing ponds (also knowns as bioponds) are only regulated in a limited number of countries.

This joint transnational strategy determines five strategic goals for reducing health risks associated with the use of urban bathing waters:

1. Improve risk identification
2. Improve monitoring - frequency, scope and methodology
3. Prevent exposure to hazards including climate change impacts
4. Improve climate-resilient management and nature-based solutions
5. Improve cross-sectoral cooperation and communication

The final chapter offers a framework for action planning for better understanding and management of risks. Potential actions are illustrated by case examples from the five countries participating in the project UrbanBlueHealth, but they are applicable in a wider context.

1 Introduction

Swimming in natural urban water bodies has become a popular form of recreation, particularly among families with children. The global rise in temperatures has significantly contributed to the increasing popularity of such urban bathing areas. Leisure activities in natural environments offer cooling relief and respite from the heat emitted by urban concrete and asphalt surfaces, delivering both physical and mental health benefits. However, alongside these benefits, natural urban bathing waters may also pose significant health risks to city inhabitants. Numerous studies indicate that surface waters in urban areas are subjected to considerable anthropogenic pressure, resulting in the presence of a wide range of chemical and biological contaminants that may pose a serious threat to public health.

Urban inland waters are frequently contaminated with municipal sewage and other urban pollutants, especially as a result of increasingly common flash floods that carry these substances into water reservoirs. Additionally, pollutants originating from agricultural runoff, particularly from industrial animal farming, are often detected in these water bodies (Farrell et al., 2021). The urban environment increases the likelihood of water coming into contact with multiple sources of contamination, such as stormwater overflows, combined sewer systems, dense networks of drainage outlets, roadway runoff, intense recreational pressure, and often the proximity of wastewater treatment plants.

Both microbiological and chemical pollutants present in bathing waters constitute a significant public health concern across Europe and globally (Farrell et al., 2021). It is also important to consider emergency events, such as uncontrolled or controlled discharges of municipal wastewater, which can lead to sudden and severe deterioration in water quality. One such example occurred in Warsaw in 2019, where millions of litres of untreated sewage were released accidentally into the Vistula River, contaminating the water with chemicals, including pharmaceuticals, heavy metals, and nitrogen and phosphorus compounds, as well as hospital-derived pathogens.

European Union legislation covers the quality of natural bathing waters since 1975. The current EU regulation is the Directive 2006/7/EC of the European Parliament and of the Council concerning the management of bathing water quality Bathing Water Directive)[1], aims to ensure a high level of protection for public health and the environment by setting minimum requirements for monitoring, classification, and management of bathing water quality across all Member States. It also obliges Member States to inform the public about water quality, potential risks, and management measures through accessible information systems. Although the Bathing Water Directive emphasizes a preventive and management-based approach, requiring the development of bathing water profiles to identify pollution sources and define measures to prevent contamination, risk-based approach is not reflected in the monitoring or management requirement. While the Bathing Water Directive provides a solid framework for ensuring the safety of recreational waters, it remains focused primarily on fecal pollution, leaving gaps in the consideration of emerging pathogens and pollutants, climate change impacts, and rapid response mechanisms. Scientific evidence shows that the minimum required monitoring frequency is insufficient for the reliable classification of bathing waters.

The Bathing Water Directive does not address artificial bathing ponds that operate without chemical disinfection, using only the natural attenuation of pathogens in a filtration zone. In this sense, these structures (also called biological or bioponds) are closer to natural bathing waters than to pools. Artificial bathing ponds are becoming increasingly popular, including in urban areas. However, artificial ponds pose

[1] Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC (https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32006L0007)

significant public health and management challenges. These artificial systems often lack regulatory clarity, standardized monitoring, and evidence-based management approaches.

2 Regulation and status of bathing waters

2.1 Natural bathing waters

National regulations in Member States transposes the Bathing Water Directive, but nationally relevant additional requirements are often defined. Below examples of national regulation and summaries of the status of natural bathing waters from the five participating countries are presented.

Austria

In Austria, bathing water quality of surface waters is regulated by the Austrian bathing waters law (Bäderhygienegesetz - BHygG, BGBl. Nr. 254/1976) and the Austrian surface bathing water regulation (Badegewässerverordnung - BGewV, BGBl. II Nr. 349/2009) which is in line with the Bathing Water Directive. It applies to all bathing waters except swimming pools, separated and treated waterbodies or waterbodies used for therapeutic purposes, and man-made water bodies that are separated from surface waters and ground water. The Regulation stipulates monitoring and classification of bathing waters, and management of water quality for bathing. It also requires informing the public about the quality of bathing waters. Every official bathing site requires establishing and maintaining a detailed bathing water profile. Monitoring of the bathing waters is required throughout the bathing season (June 15th to August 31st) and is carried out by the district administrative authority on order of the Austrian Ministry of Health. The monitoring frequency according to the Austrian surface bathing water regulation is a minimum of five samplings evenly distributed over the bathing season. Results are published online on a website of the Austrian Health Ministry (https://www.ages.at/umwelt/wasser/badegewaesser-monitoring) hosted by the Austrian Agency for health and food safety (AGES). Currently, 260 bathing sites defined as "EU-bathing sites" are listed. In case a bathing site has been classified as "poor" for five consecutive years,

the Provincial Governor must revoke its designation as a bathing site. They must also inform the public of the reasons for the revocation and permanently advise against bathing by means of clearly visible signs in the shore area.

Croatia

In Croatia, the quality of inland bathing waters is regulated by the Regulation on Bathing Water Quality (OG 51/2014), which transposes the Bathing Water Directive. The Regulation sets requirements for monitoring, classification, and public information, with local self-government units responsible for site management and Croatian Waters (Hrvatske vode) in charge of processing monitoring data and classifying bathing water quality.

Designated bathing sites are officially declared by local authorities, accompanied by bathing water profiles, monitoring points, and a seasonal sampling calendar prepared by accredited laboratories. Croatian Waters maintains a publicly accessible online platform (https://vrtlac.izor.hr/kakvoca) where data on both coastal and inland bathing waters are displayed.

The Croatian Regulation is stricter than the EU Directive, requiring at least five samples per season (vs. four under the Directive) and a total of 20 samples over four years (vs. 16). It also evaluates individual samples during the season, with results graded only as "excellent" or "good." Exceedances are treated

as short-term pollution events, triggering additional sampling. Importantly, the Regulation stipulates that water samples are not collected after rainfall, though in practice, people continue to bathe, which may give misleading impressions of safety.

During the 2024 season, 27 inland bathing sites were monitored across 13 locations, mostly on lakes and rivers. The majority were rated "excellent" or "good," though some sites were not classified due to insufficient sampling. Under national rules, 50 % were rated "excellent" and 30 % "good," while EU criteria gave slightly higher "excellent" ratings (55 %).

As of 2025, Croatia has integrated its web platforms for sea and inland bathing waters into a single online application with enhanced search functions, site photos, and information on facilities. This upgrade has improved visibility, boosted tourism potential, and established the platform as a trusted public information tool.

Czech Republic

In the Czech Republic, the management of bathing waters is grounded in the transposition of the Bathing Water Directive, with national implementing legislation consisting of the Decree No. 238/2011 Coll. under the Public Health Protection Act. According to reporting to the European Environment Agency (EEA), Czech authorities identified 156 inland bathing sites in 2022 and classified them using the two microbiological indicators required by the Directive: *Escherichia coli* and intestinal enterococci. Each bathing site must have a monitoring calendar established before the season, with at least one sample per month and a minimum of four samples over the season, plus a pre-season sample. The monitoring and classification system follow EU guidance: sites are categorized as "excellent," "good," "sufficient," or "poor" based on percentile thresholds of the two key bacteria indicators. In 2022, 76.9 % of Czech sites were classified as "excellent," another 12.8 % as "good," and none as "poor," demonstrating strong overall performance. Importantly, the monitoring regime is designed to detect "short-term pollution events" (e.g., following heavy rain) and requires corrective measures when thresholds are exceeded.

In terms of management, each bathing site is required to have a site profile that identifies potential sources of contamination and outlines mitigation measures—consistent with Article 13 of the Bathing Water Directive. In practice, Czech management has included actions such as sediment removal, reservoir aeration, bank rehabilitation, intensified wastewater treatment, and aquaculture control in bathing catchments. Public information is also mandated: results must be made available via information boards at sites, through the media, and online — supporting transparency and public participation.

Despite generally strong classification outcomes, Czech bathing waters face persistent challenges. Large-scale blooms of cyanobacteria remain a recurring problem in reservoirs and ponds, linked to eutrophication and rising temperatures. Some sites still experience microbiological or parasitic risk, and limitations in chemical-pollutant monitoring are acknowledged. Moreover, 8.3 % of sites in 2022 were "not classified," often due to incomplete monitoring data or new site status.

Hungary

In Hungary, the quality of natural bathing waters is regulated by Government Decree No. 78/2008 (IV. 3.), which transposes the Bathing Water Directive into national legislation. The Decree defines the rules for designating bathing sites, monitoring and assessing water quality, and providing public information. Oversight of bathing water quality is carried out by the National Center for Public Health and Pharmacy. in cooperation with regional public health authorities and water management agencies. Designated bathing

waters include lakes, rivers, quarries, and artificial water bodies that meet the required safety and infrastructure standards. Each bathing site must have a bathing water profile, which identifies potential pollution sources, outlines preventive and corrective measures, and assesses risks such as wastewater discharges, agricultural runoff, or algal blooms. The bathing season in Hungary usually runs from June to September, during which regular monitoring is conducted (one preseason sample and at least 3 monthly samples during the season).

The monitoring programme focuses on two microbiological indicators of faecal contamination (*Escherichia coli* and intestinal enterococci) using EU-standardized methods. Based on four years of data, bathing waters are classified as excellent, good, sufficient, or poor. In addition to microbiological testing, visual inspections are carried out to identify cyanobacterial blooms, surface pollution or macrophyte growth. If visual signs of cyanobacteria are present, additional testing for chlorophyll, cyanobacterial dominance and toxin production is carried out. These parameters are assessed against national limit values. Information on bathing water quality is made publicly available through an interactive online platform managed by the National Public Health Centre, as well as on-site information boards displaying the current classification and any bathing restrictions. Public engagement and transparent communication are integral parts of the management system, ensuring that bathers are informed about water safety and any temporary pollution events. Management practices focus on preventing contamination through improved wastewater treatment, catchment management, and stormwater control. In some lakes and reservoirs, local authorities implement additional measures such as aeration, sediment removal, and vegetation management to reduce nutrient loads and minimize algal growth.

Over 85% of Hungarian bathing waters are classified as “excellent” or “good.” However, challenges persist in managing short-term pollution events, cyanobacterial blooms, and emerging contaminants. Ongoing integration of risk-based approaches, climate adaptation measures, and enhanced monitoring practices remains crucial for safeguarding public health and ensuring the sustainability of Hungary’s natural bathing waters.

Poland

In Poland, bathing water quality is regulated by the Regulation of the Minister of Health of 17 January 2019 on the supervision of bathing water quality and water at sites occasionally used for bathing (Journal of Laws 2024, item 255). This regulation transposes the requirements of the EU Bathing Water Directive (2006/7/EC) into national law and applies to both officially designated bathing sites and those occasionally used for bathing. It sets out the scope, frequency, and methods for testing bathing water quality, ensuring compliance with European standards.

All of natural water bodies in Poland are owned by the State Water Holding “Wody Polskie,” while the monitoring of bathing water quality is carried out by the State Sanitary Inspection. The system emphasizes transparency: results from water quality testing at individual bathing sites are published online via the Bathing Service platform (https://sk.gis.gov.pl/). The platform includes an interactive map that provides daily, up-to-date information on bathing site status, including whether a site is open or closed for use.

2.2 Artificial bathing ponds (biological ponds)

National regulations apply to artificial bathing ponds in Austria, Croatian and the Czech Republic. No dedicated regulation is in place in Hungary and Poland.

In Austria, artificial small bathing ponds are governed by the Bathing Hygiene Regulation (Bäderhygieneverordnung 2012 – BHygV 2012, BGBl. II Nr. 321/2012). Tables 3.2.4.1 and 3.2.4.2 of the regulation summarize the key structural and operational requirements, and maximum allowable levels for microbiological and chemical-physical parameters mandated by this regulation. A significant current drawback, however, is the lack of a precise, unambiguous definition delineating what constitutes a artificial small bathing pond under the scope of the Bathing Hygiene Regulation.

In Croatia artificial small bathing ponds are governed by the Ordinance on the sanitary-technical and hygienic conditions of swimming pools and on the health safety of swimming pool waters (Official Gazette 59/2020) as "biological pool". In Croatia, currently there is only one registered artificial pond.

In Czech Republic, the first public bathing ponds was opened in 2007 in Kovalovice (by 2024 there were already 40 in operation). Bathing ponds were included in Czech legislation in 2011, and the requirements for monitored indicators, their monitoring and evaluation were also defined. Since there was no experience with bathing ponds in Czech at that time, the requirements were inspired by German and Austrian regulations. Currently, the Act on Public Health Protection (No. 258/2000 Coll.) defines a bathing pond as "a building permitted for bathing purposes equipped with a system of natural bathing water purification". Decree of the Ministry of Health No. 238/2011 Coll. requires the detection of indicators of faecal contamination of *Escherichia coli* and intestinal enterococci and transparency (visibility depth). The detection of *Pseudomonas aeruginosa* was cancelled in 2014 due to unresolved methodological reasons. The current legislation concerning bathing ponds is certainly not perfect and during the next revision of the legislation it would be appropriate to improve/update the definitions and requirements. Structural and operational requirements are not determined by Czech legislation; the operators are usually inspired by Austrian requirements. Since 2014, there are standards for the planning, construction and operation of swimming ponds and biopools, created by the Biopools and Ponds Association (BPA). But it is not a mandatory regulation.

The increasing public demand for natural, chemical-disinfectant-free bathing opportunities in Austria, coupled with pressure from the commercial market, has resulted in increasing numbers of public artificial small bathing ponds. Although originally not intended as competition to conventional chlorinated swimming pools, the structural design of many contemporary artificial bathing ponds is increasingly reminiscent of traditional pools, yet they lack the corresponding costly water treatment infrastructure. Furthermore, practical implementation national and international acknowledged standards specific to these artificial pools are currently not available. Conventional chlorinated pools achieve hygienic safety through rigorous operational control which ensures disinfectant efficacy and the depot effect provided by chemical disinfectants. Conversely, artificial small bathing ponds, which lack chemical disinfection, cannot offer the same hygienic safety guarantee even when their operational and structural legal requirements are met according to the bathing hygiene regulation. Consequently, short-term management interventions, such as those required to mitigate a pathogen-shedding event, are limited. The only effective management option currently available for controlling potential infection risks remains the limiting of bather numbers, which functionally results in the dilution of potential pathogens. To address this, the Austrian regulation requires a total minimum water volume of 10 m^3 per bather per day, same as in Croatia. However, enforcement of this bather limit remains a significant challenge. Without the continuous microbicidal barrier of a residual disinfectant, the water quality is highly vulnerable to contamination events (e.g., high bather load, sudden faecal shedding, or heavy rainfall runoff), potentially leading to elevated pathogen levels. Moreover, regarding long-term management there is currently a considerable data deficit concerning the complex ecology of these systems and its subsequent effect on microbiological water quality. Crucially, the relationship between pond design elements (regeneration zone size, hydraulic retention time, sediment composition, filters, foil material, etc.) and the behavior of faecal indicator organisms and opportunistic pathogens remains poorly characterized. This knowledge gap is particularly pronounced when technical

facilities, such as filtration systems, are incorporated, as these features may inadvertently promote the proliferation of opportunistic pathogens such as *Pseudomonas* spp.

Table 1 summarizes the most important structural and operational requirements for artificial bathing ponds of Austria, Croatia, and Czech Republic, Table 2 gives an overview over the limit values of the microbiological and chemical-physical parameters of each country.

Table 1. Summary of structural and operational requirements of artificial bathing ponds in Austria, Croatia, and Czech Republic.

	Austria	Croatia	Czech Republic
Structural requirements			
structural design	• Artificial • Intended for bathing purposes • Total surface area ≤1.5 ha • average water depth of bathing zone ≥1.8 m • Sealed off from groundwater	• Artificial • Intended for bathing purposes • Depth of bathing area ≥0.8 m, except directly along the shore • Dimensioned so that there is a possibility of adding 5% of the total water volume within 24 h • Access areas must be safe and designed in such a way as to prevent the resuspension of sediment to the greatest extent possible • Do not require a foot disinfection basin or side shower system	• Artificial • Intended for bathing purposes • BPA*: water purification factors include functional communities of plankton, invertebrates and macrophytes, which are dimensioned to handle the expected pollution; permanently limited phosphorus concentration
Regeneration zone (RZ)	• Mandatory regeneration zone • Must be planted • Must be ≥1/3 of total surface area	• Mandatory regeneration zone • Must be planted • Must be ≥50% of total surface area	• Not determined by legislation • BPA: Must be ≥50% of total surface area must be completely planted with plants, the necessary water

	Austria	Croatia	Czech Republic
	• Must be physically separated from the swimming area • Must form a continuous surface with the swimming area	• Must be physically separated from the swimming area • The water surface must be uninterrupted	exchange between both zones • the average depth at least 1.8 m, double-permeable "intermediate bottoms" are permissible, sedimentation is supported
Additional technical facilities	• Allowed: Filters Fining ponds	Additional equipment and technological processes may be used in the pool water of the biological pool if they improve the preparation of the pool water in the biological pool and the hygienic quality of the water and if they do not cause biological damage.	• Not specified by legislation • BPA: Skimmer, mineralization filter, slow filters, discontinuously operated filters, splashed non-flooded filters, interval filters
Operational requirements			
Water treatment	• Water processing is carried out exclusively via ecosystem cycles of micro- and macro-organisms • May be assisted by technical means; if applied, those must not form aerosols	Additional devices, equipment and technological processes in the pool water must not generate aerosols.	• Not specified by legislation, the natural method of treatment follows from the definition
Disinfection	No treatment allowed that is harmful to micro- and macro-organisms (UV-Disinfection, chlorination, fungicides, algaecides…)	The use of chemical cleaning agents and disinfectants is not permitted for biological pools.	• The natural method of treatment follows from the definition, no disinfection is allowed

	Austria	Croatia	Czech Republic
			• BPA: No disinfection
Water temperature	artificial heating of fill water or bathing water is not allowed	The filling water and the pool water of the biological pool may be artificially heated until the temperature of the pool water reaches 23°C.	• Not specified by legislation • BPA: ≤25°C
Bather load/day	Is calculated of the total water volume (m^3; RZ included) divided by 10	Is calculated of the total water volume (m^3; RZ included) divided by 10. The permitted number of bathers who can be in the pool water at the same time is 20% of the permitted number of visitors per day. Short-term exceedances of the permitted number of bathers are permitted up to 5% of the permitted number of visitors per day.	• Not specified by legislation
Animals	• Fish stocking is not allowed • Waterfowl has to be kept out	There must be no waterfowl or fish in the bathing area with a biological pool.	• Not specified by legislation

*BPA: requirements defined in the standards developed by the Biopools and Ponds Association.

Table 2. Maximum allowable levels of microbiological and chemical-physical parameters of artificial bathing ponds in Austria, Croatia, and Czech Republic.

	Austria	Croatia	Czech Republic
Microbiological parameters			
E. coli	100 cfu / 100 ml (ISO 9308-3)	100 cfu / 100 ml (ISO 9308-1 or ISO 9308-2)	100 cfu / 100 ml (ISO 9308-1 or ISO 9308-3)

	Austria	Croatia	Czech Republic
Intestinal Enterococci	50 cfu / 100 ml (ISO 7899-1 or ISO 7899-2)	50 cfu / 100 ml (ISO 7899-2)	50 cfu / 100 ml (ISO 7899-1 or ISO 7899-2)
Pseudomonas aeruginosa	25 cfu / 100 ml (ISO 16266)	10 cfu / 100 ml (ISO 16266)	–
Salmonella	not detected / 1 l (ISO 19250) only to be determined in case waterfowl has access to the bathing water	0 / 1000 ml (ISO 19250) where waterfowl are present	–/
Legionella spp.	–	10 cfu / 100 ml (ISO 11731) before the pool starts operating	–
Staphylococcus aureus	–	100 cfu / 100 ml (SM 9213 B) analysed once a month	–
Number of colonies at (36±2)˚C/ (44±4) h	–	500 cfu / ml (ISO 6222)	–
Chemical-Physical parameters			
Visibility depth	≥2 m	2 m	≥1 m BPA*: to the bottom, minimal value 1.8 m
Dissolved O_2	≥80 % saturation	≥80 % saturation	Only BPA: 80 - 120 %
pH	6.0 - 9.0	6.0 - 8.5 Exceptionally 9.0	Only BPA: 8.0-8.5
Total phosphorus	20 µg/l	20 µg/l	Only BPA: 35 µg/l

	Austria	Croatia	Czech Republic
Colour	no colour deviation	Acceptable to users and without unusual changes	–
Ammonium	–	0.3 mg/l	Only BPA: Ammonium nitrogen 0,5 mg/l for supplementary water
Mineral oils	–	not found Field measurement.	–
Electrical conductivity (at 20 °C)	–	200 - 1000 µS/cm	Only BPA: 1000 µS/cm
Temperature	–	≤26 °C For a short time, during a heat wave (depending on circumstances), the value may be higher.	Only BPA: ≤25 °C
Surfactants (foam on the surface)	–	not found field measurement	–
Solids (floating objects, debris, reeds, etc.)	–	not found field measurement	–
Odour	–	Acceptable to users and without unusual changes. Field measurement.	–

*BPA: requirements defined in the standards developed by the Biopools and Ponds Association.

3 Challenges for urban bathing sites

The Transnational urban bathing water SWOT analysis of partner countries (D1.1.3) provides an integrated overview of the strengths, weaknesses, opportunities, and threats related to urban bathing waters across Central Europe. Its importance lies in highlighting shared challenges, such as problematic water quality, infrastructure gaps, and climate-related risks, while also recognizing common strengths like established monitoring systems and institutional frameworks. By comparing national perspectives, the analysis reveals patterns that are relevant across borders and identifies issues that require joint solutions rather than isolated national responses. Building on these insights, this Joint transnational strategy will provide suggestions and improvement measures targeted as the key goals identified in the transnational SWOT, ensuring that partners can translate the analysis into concrete actions for safer, more sustainable, and more attractive urban bathing sites as part of the project UrbanBlueHealth. These challenges are shared by many countries outside the project consortium; thus, solutions can also be transposed to other settings.

3.1 Risk based approach and identification of human health risks

Despite clear WHO recommendations, most partner countries lack the systematic implementation of the WHO risk-based approach to bathing water management, as outlined in the Recreational Water Safety Plan (RWSP) framework[2]. Current practices remain largely reactive, relying on periodic microbiological testing rather than preventive risk assessment and continuous control of contamination sources. The WHO framework emphasizes proactive identification of hazards, assessment of exposure pathways, and establishment of control measures and contingency plans to prevent health risks from pollution events such as heavy rainfall, algal blooms, or sewage overflows. Without such an integrated approach, risk management remains fragmented, limiting the ability of authorities to anticipate and mitigate threats to public health, particularly under increasing pressures from climate change and urbanization.

The first step in applying risk-based approach is the identification and characterization of potential risks. This chapter provides overview of possible microbiological and chemical risks relevant to urban bathing sites, where complex interactions between human activity (such as wastewater discharges, surface runoff, animal activity, industrial pollution) and environmental conditions can compromise water quality. Understanding these risks forms the basis for targeted monitoring, informed decision-making, and effective preventive management.

Microbiological contamination of surface waters

Microbiological contamination of surface waters represents a major environmental and public health concern. It primarily arises from the discharge of untreated or insufficiently treated wastewater, agricultural runoff, and stormwater overflows carrying pathogens of human or animal origin. These microorganisms (such as bacteria, viruses, and protozoa) can persist in aquatic environments and pose health risks to recreational users through direct contact, ingestion, or inhalation. Understanding the sources, behaviour, and persistence of microbial contaminants is therefore essential for effective water quality monitoring, management, and the protection of public health.

[2] WHO Guidelines on recreational water quality: Volume 1 Coastal and fresh waters (2021) https://www.who.int/publications/i/item/9789240031302

Viruses

A systematic review encompassing 60 studies from 18 European countries revealed that as many as 29% of 8,118 analysed bathing water samples tested positive for organisms of public health significance, including viruses, bacteria, and protozoa (n = 303)[3]. The analysis indicated that adenoviruses were the most frequently detected viral agents, found in 68% of the tested samples. In another study, one-third of the water samples were positive for one or more viruses, despite meeting the bacteriological standards set by the Bathing Water Directive. Adenoviruses were suggested as potential markers of human faecal contamination Other viruses detected in bathing water include noroviruses, which are major enteric pathogens in humans. During epidemic periods, SARS-CoV-2The risk of exposure in recreational waters requires further investigation (Farrell *et al*., 2021).

Bacteria

Pathogenic bacteria have been identified in waters that meet the quality standards outlined by the Bathing Water Directive. These include *Salmonella* spp. (notably *S. enteritidis*, *S. typhimurium*, and *S. derby*), as well as *Campylobacter jejuni/coli* and *Yersinia intermedia*[4].

Among the autochtonous pathogenic and opportunistic bacteria detected in inland surface waters, species of *Vibrio,* including *V. parahaemolyticus*, non-toxigenic *V. cholerae*, and *V. vulnificus,* are of particular concern, which may cause wound and tissue infections, gastroenteritis and even sepsis in immunocompromised individuals). *V. cholerae* strains identified in European surface waters were not associated with epidemic serotypes responsible for cholera. Vibrios do not correlate with traditional faecal indicator bacteria, but strongly correlate with water temperature. As a result of climate change, vibrios pose increasing health risk to bathers[3].

Protozoa

Studies conducted in recreational bathing waters have detected the presence of parasitic protozoa *Cryptosporidium* spp. and *Giardia* spp. in 17% of the tested samples. Importantly, standard bacterial indicators correlate poorly with the presence of these parasites. This highlights the need to expand the legally required monitoring panel to include parameters that better reflect parasitic threats. It has been demonstrated that *Clostridium perfringens* bacteria show a good correlation with protozoa from the genera *Cryptosporidium* and *Giardia*, as well as with *Salmonella*, adenoviruses, and enteroviruses. Therefore, its spores have been proposed as an additional indicator of faecal contamination[3,5] (Farrell *et al*., 2021; Rodrigues and Cunha, 2017).

[3] Farrell, M.L., Joyce, A., Duane, S., Fitzhenry, K., Hooban, B., Burke, L.P. and Morris, D., 2021. Evaluating the potential for exposure to organisms of public health concern in naturally occurring bathing waters in Europe: A scoping review. Water Research, 206, p.117711.

[4] Hokajarvi, A., Pitk¨anen, T., Siljanen, H M.P., Nakari, U., Torvinen, E., Siitonen, A., Miettinen, I.T, 2012. Occurrence of thermotolerant Campylobacter spp. and adenoviruses in Finnish bathing waters and purified sewage effluents. J. Water Health 11, 120–134.

[5] Rodrigues, C., Cunha, M.ˆA., 2017. Assessment of the microbiological quality of recreational waters: indicators and methods. Euro-Mediterranean J. Environ. Integr. 2 (1), 1–18.

Antimicrobial Resistance (AMR)

In the context of the global spread of antimicrobial resistance, reports of AMR genes detected in bathing water are particularly concerning. Antibiotic-resistant bacteria were identified in almost half of the investigated sites, including *E. coli* producing extended-spectrum beta-lactamases (ESBL) in waters classified as "good" according to the Bathing Water Directive. Enterococcus strains resistant to aminoglycosides were also detected, along with genes conferring resistance to other commonly used antibiotics in human medicine[3,6]). Among *Vibrio* species isolated from bathing water, a study found 81 out of 82 isolates exhibiting resistance to selected antibiotics, including multidrug-resistant strains[7]. In the context of inland waters used for recreation, the main sources of antimicrobial resistance include runoff from industrial animal farming, discharges from household and municipal wastewater treatment plants (which often receive effluent from hospitals), faeces from aquatic animals — particularly waterfowl — as well as bacteria introduced by bathers and dogs[3,8] (Farrell *et al*., 2021; Hooban *et al*., 2020).

Cyanobacteria

Cyanobacteria (blue-green algae) commonly found in standing recreational waters, including urban waters. While cyanobacteria are part of the natural aquatic ecosystem, under specific conditions (increasing water temperature, phosphorous discharge) can proliferate disproportionally, resulting in algal blooms. Algal blooms are not only aesthetically unpleasant (causing discoloration, increased turbidity, foaming or matting) but can also produce a variety of toxins, including microcystins, anatoxin-a, and cylindrospermopsin. Microcystins are known for their hepatotoxic effects, anatoxin-a is a potent neurotoxin, and cylindrospermopsin exhibits both cytotoxic and genotoxic properties[9]. In humans, exposure during bathing may occur via dermal contact, accidental ingestion of water, or inhalation of water aerosols. Symptoms can include skin rashes, nausea, diarrhea, abdominal pain, and, in severe cases, liver damage[10].

Seasonality of microbial exposure

Studies have shown that the highest detection rates for viruses and bacteria occur at the peak of the bathing season (July-August), while protozoa are most frequently detected in spring and early summer — patterns associated with rainfall and runoff. Research has also confirmed both diurnal and seasonal variability in water quality, indicating that a single, small-volume sample (100 mL) collected once per month may not accurately reflect the actual health risk on any given day.

[6] Di Cesare, A., Eckert, E.M., Teruggi, A., Fontaneto, D., Bertoni, R., Callieri, C., Corno, G., 2015. Constitutive presence of antibiotic resistance genes within the bacterial community of a large subalpine lake. Mol. Ecol. 24, 3888-3900.

[7] Lepuschitz, S., Baron, S., Larvor, E., Granier, S.A., Pretzer, C., Mach, R.L., Farnleitner, A. H., Ruppitsch, W., Pleininger, S., Indra, A., Kirschner, A.K.T, 2019. Phenotypic and genotypic antimicrobial resistance traits of Vibrio cholerae Non-O1/Non-O139 Isolated from a Large Austrian Lake frequently associated with cases of human infection. Front. Microbiol. 10.

[8] Hooban, Brigid., Joyce, Aoife., Fitzhenry, Kelly., Chique, Carlos., Morris, Dearbh´aile, 2020. The role of the natural aquatic environment in the dissemination of extended spectrum beta-lactamase and carbapenemase encoding genes: a scoping review. Water Res. 180, 115880.

[9] Pronin E. Are the existing guidelines sufficient for the assessment of bathing water quality? The example of Polish lakes. Environ Sci Pollut Res Int. 2021 Aug;28(29):39742-39756. doi: 10.1007/s11356-021-13474-9.

[10] Funari E, Testai E. Human health risk assessment related to cyanotoxins exposure. Crit Rev Toxicol. 2008;38(2):97-125.

Human health consequences of microbial exposure

Acute health risks associated with bathing in contaminated waters include gastrointestinal infections (caused by noroviruses, adenoviruses, *Salmonella*, and *Campylobacter*) and wound infections or sepsis (associated with *Vibrio* spp.). Moreover, exposure to AMR (antimicrobial-resistant) bacteria may lead to gastrointestinal colonization and subsequent transmission within the population—especially among vulnerable individuals[3,8] .

In the case of protozoa such as *Cryptosporidium*, outbreaks have been reported even in treated waters (e.g., swimming pools) due to the resistance of oocysts to standard chlorine levels. In urban open waters with intense recreational use, the risk of contact with such pathogens increases — particularly if the watershed feeding into the bathing reservoir includes livestock farms, especially cattle operations.

From a public health perspective, urban bathing sites represent high-risk areas for exposure to a wide array of waterborne pathogens: viruses (including adenoviruses and noroviruses), bacteria (*Vibrio*, *Salmonella*, *Campylobacter*, *Enterococcus*, *E. coli* ESBL), and protozoa (*Cryptosporidium*, *Giardia*). Notably, the presence of these microorganisms has been confirmed in waters that meet legally mandated bacteriological standards, underscoring the limitations of the current narrow panel of indicators and the low frequency of sampling[3].

Chemical contaminants in surface waters

Chemical contaminants in surface waters originate from a wide range of anthropogenic activities, including industrial discharges, agricultural runoff, wastewater effluents, and urban stormwater. These pollutants encompass nutrients, heavy metals, pesticides, pharmaceuticals, and other emerging contaminants that can persist in the environment and accumulate in aquatic organisms. Even at low concentrations, many of these substances can have toxic, mutagenic, or endocrine-disrupting effects, posing risks to both ecosystems and human health. Understanding the occurrence, sources, and behaviour of chemical contaminants is therefore crucial for assessing water quality and ensuring the sustainable management of aquatic environments.

Pharmaceuticals and personal care products (PPCPs)

Pharmaceuticals such as non-steroidal anti-inflammatory drugs (e.g., ibuprofen, diclofenac), antibiotics, steroid hormones, and UV filter compounds are regularly detected in surface waters across Europe. Recreational exposure may occur through ingestion of small amounts of water or direct dermal contact. Studies have demonstrated that these compounds can act as endocrine disruptors, and contribute to the development of antimicrobial resistance in the environment[11]. The presence of antibiotics in water promotes the selection of resistant bacterial strains, which may colonize the gastrointestinal tract of bathers, posing a significant health risk.

Per- and Polyfluoroalkyl Substances (PFAS)

PFAS, commonly referred to as "forever chemicals", are characterized by their extreme environmental persistence, high mobility, and strong bioaccumulative potential). Their presence has been confirmed in

[11] Antimicrobial resistance in surface waters – developing environmental monitoring for better risk management. European Environment Agency, 2025. https://www.eea.europa.eu/en/analysis/publications/antimicrobial-resistance-in-european-surface-waters-a-developing-area

European waters near wastewater treatment plants and urbanized areas[12]. These substances have been linked to metabolic disorders, immune suppression, disruptions in lipid and hormonal homeostasis, and an increased risk of certain cancers, including kidney and testicular cancer (;. The health risk through recreational exposure is currently unknown.

Heavy Metals

Lead, cadmium, mercury, nickel, and zinc are frequently detected in river water and sediments in Europe. Elevated concentrations of these metals have been reported in the sediments of the Vistula and Oder rivers, as well as in recreational reservoirs, such as Lake Bagry in Kraków[13] . Human exposure during recreational water activities may occur via dermal absorption or accidental ingestion. Cadmium and lead exhibit neurotoxic and nephrotoxic properties, and chronic exposure can lead to developmental disorders in children, anaemia, and damage to the nervous system. Mercury accumulates in tissues and is associated with neurobehavioral disorders.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs, detected for example in the waters of the Blachownia reservoir, are byproducts of fuel combustion and industrial processes. Many of these compounds, e.g. benzo[a]pyrene, have well-documented carcinogenic and mutagenic properties. Exposure during bathing may occur through ingestion of contaminated water or dermal contact.

3.2 Limitations of the current monitoring methodologies

The microbiological methods used for reference analyses of bathing water are standardised. This is important because microbiological methods are not robust, and different principles or methods can lead to different results, making it impossible to compare results and evaluate them over longer time series (e.g. in information systems or for reporting). It is therefore necessary for the methods to provide reliable and robust results across the entire range of bathing waters (from oligotrophic lakes to eutrophic ponds and rivers), and alternative methods need to be carefully assessed for equivalence.

Current European legislation Bathing Water Directive (2006/7/EC) prescribes the determination of two basic microbiological indicators of faecal contamination, namely *Escherichia coli* and intestinal enterococci. The legally prescribed methods for inland water analysis are EN ISO 9308-1 and 9308-3 for *E. coli* and EN ISO 7899-1 and 7899-2 for intestinal enterococci.

[12] PFAS pollution in European waters. European Environment Agency, 2025. https://www.eea.europa.eu/en/analysis/publications/pfas-pollution-in-european-waters.

[13] Bielski A., Czaplicka A. Heavy Metals in Post-Exploitation Reservoirs—The Bagry Lake Case Study (Poland). Appl. Sci. 2023, 13(10), 5884. https://doi.org/10.3390/app13105884.

Detection of intestinal enterococci and Escherichia coli

Intestinal enterococci

The performance of the method for intestinal enterococci detection according to EN ISO 7899-2 (membrane filtration of samples, cultivation on selective Slanetz Bartley agar and confirmation on bile aesculin agar) a) is satisfactory. It is a group indicator (although the method may be focused on the detection of faecal species *E. faecalis, E. faecium, E. durans and E. hirae*). The method recovers several species, each of which may have a different ecology. Although most species of enterococci originate from the faecal environment, but some species/strains proliferation, for example, in sediment or on plant debris. . Other microorganisms may also interfere with the detection (e.g. *Lactobacillus plantarum* in eutrophic waters in midsummer, Fig. 1). The method is sensitive, with a lower limit of detection (LOD) of 1 colony forming unit (CFU)/100 ml.

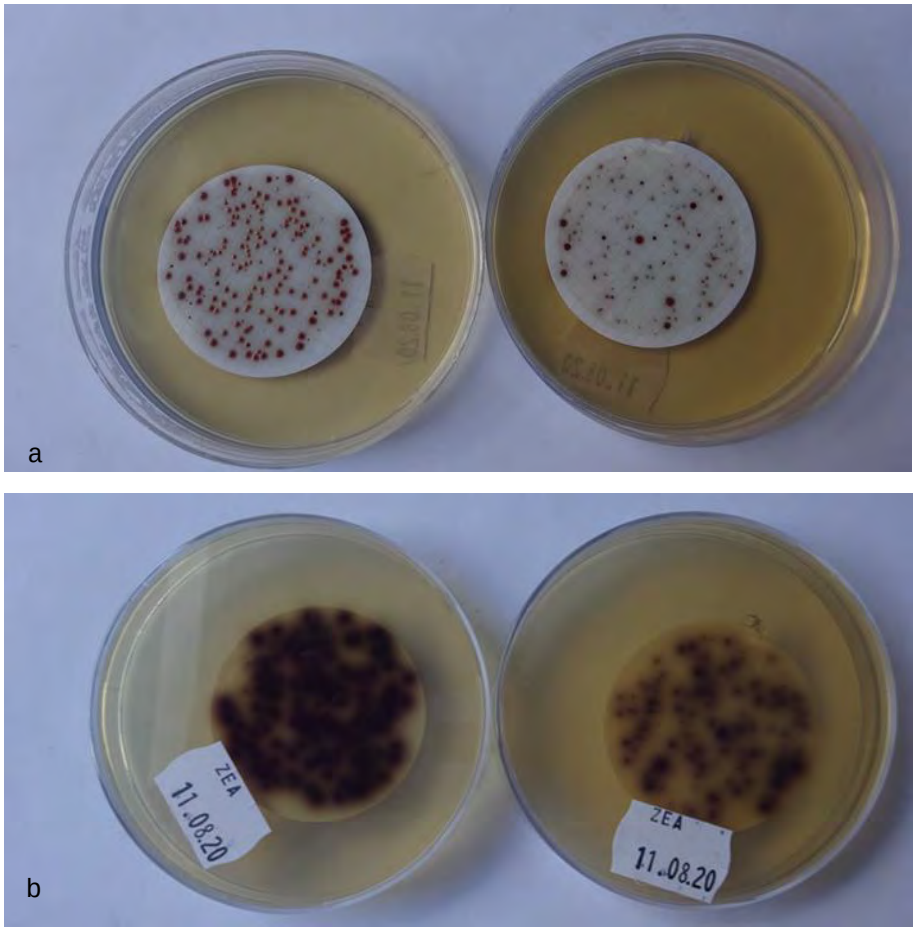

Figure 1a and 1b. Detection of intestinal enterococci according to EN ISO 7899-2. The same membrane filters are shown from above and below. Colonies on the left membrane filters are coloured typically (dark rec colonies with positive (dark brown) bile aesculin test. On the right-side filters there is only 6 typical colonies of enterococci, but more than 60 colonies of *Lactobacillus plantatum* (yellow brown colonies with positive bile aesculin test).

The method for intestinal enterococci detection according to EN ISO 7899-1 (miniaturized method based on ß-D-glucosidase activity detection) has a detection limit of 15 MPN/100 ml, which is too high for clean

water. In the case of a result <15 MPN/100 ml, the water is perfectly suitable for bathing, but this is not ideal for statistical processing of the results.

Escherichia coli

EN ISO 9308-1 is not suitable for types of water with a high background microbiota, which is typical for Central European freshwaters. High background distorts the analysis leading to and inaccurate readings (Fig. 2). Several autochthonous microorganisms (e.g. *Aeromonas* species) appear as false positives.

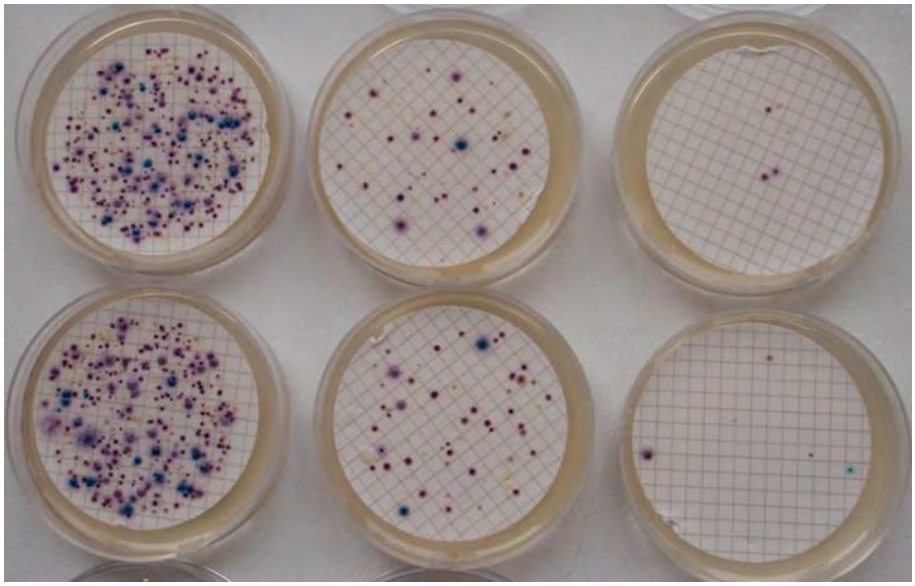

Figure 2. Detection of *E. coli* according to EN ISO 9308-1 of water with a high background microbiota, which is typical for Central European freshwaters.

The method for *E. coli* detection according to EN ISO 9308-3 (miniaturized method based on ß-D-glucuronidase) has a detection limit of 15 MPN/100 ml, which is too high for clean water. In the case of a result <15 MPN/100 ml, the water is perfectly suitable for bathing, but this is not ideal for statistical processing of the results.

Standard methods in development

There is a draft ISO 9308-4 standard in development for the determination of *E. coli*, which prescribes a membrane filtration method on TBX chromogenic medium at a selection temperature of 44 °C with a resuscitation step of 4 hours at 36 °C. Validation studies of this method are currently being organized. Laboratories of project partners contributed to this process.

The recently published ISO 7899-3 standard for the detection of intestinal enterococci is primarily intended and has been validated for drinking water. It is unlikely that it will become the reference method for the determination of intestinal enterococci in bathing water, further validation. On the other hand, a method analogous to the method for the detection of *E. coli*: EN ISO 9308-2 would greatly facilitate the detection of enterococci in certain types of water (e.g. Central European freshwaters with high background microbiota).

Other methodological constraints

Sediment and sand as underestimated sources of pathogens

Water in recreational areas is regularly monitored, but little or no attention is paid to another source of potentially pathogenic bacteria, especially aerobic or microaerophilic bacteria: beach sediments and sand. Children often play in the littoral zone, thus being directly exposed to sediment and sand[14]. Introducing sediment and/or sand monitoring was suggested in many studies. Investigated parameters include opportunistic pathogens *Clostridium perfringens* and thermotolerant campylobacters together with *E. coli* and intestinal enterococci which can be tested as indicators of faecal pollution.

"Too little, too late"

Standard water testing methods take 24-48 hours from sampling to results, and due to communication barriers present in many countries, results may take even longer to reach public health authorities or beach operators and to inform preventive or remedial actions. Monitoring faecal indicators may provide information on sewage-derived pathogens (though predictive power for viruses and protozoa has been challenged due to their different environmental survival characteristics) but gives no indication to the presence or proliferation of autochthonous microorganisms such as cyanobacteria and vibrios. With monthly sampling, regulatory monitoring will clearly not provide up-to-date information on water quality.

Several potential solutions were suggested to overcome these limitations. Rapid nucleic acid-based testing methods can provide results within hours instead of days. Daily early morning testing for enterococci by quantitative polymerase chain reaction (qPCR) and immediate posting of results is the approach used successfully in the Great Lakes region, US. Other countries, including the United Kingdom, opted for hydrological modelling using historical water quality and meteorological data, among others, to provide reliable prediction on water quality on a given day. More recently remote sensing methods and in situ water quality sensors were proposed as suitable early warning tools indicating changes in water quality.

3.3 Climate change impact on bathing sites

Climate change increasingly affects urban bathing water quality through rising water temperature and more frequent extreme weather events, such as heavy rainfall, floods, and droughts.

Rising water temperatures

One of the most noticeable effects of climate change on bathing sites is the increase in both air and water temperatures. Warmer temperatures promote the growth of phytoplankton, particularly cyanobacteria (blue-green algae), which are commonly found in ponds, lakes, and reservoirs. These organisms can form extensive water blooms when there is sufficient sunlight and nutrients (especially nitrogen and phosphorus), which not only degrade the aesthetic value of bathing waters but can also produce toxins harmful to human health.

[14] Chávez-Díaz L.V., Gutiérez-Cacciabue D., Poma H.R. (2020): Sediments quality must be considered when evaluation freshwater aquatic environments used for recreational activities. International Journal of Hygiene and Environmental Health 223:159-170.

Cyanobacteria can release substances (e.g., microcystin) that may cause skin irritation, allergic reactions, and more serious health issues such as liver or nervous system damage.

With increasingly prolonged warm periods, the season of cyanobacteria presence extends and intensifies, meaning that blooms appear earlier in the spring and persist into the autumn. This trend has been observed in several reservoirs in the central Europe. Species distribution of cyanobacteria also shifts geographically with climate change.

Warming water temperatures also contribute to the proliferation of authochthonous opportunistic pathogens, such as non-toxin producing *Vibrio cholerae.* The association is so strong, that the European Center for Disease Control operates a temperature-based early warning system for the risk of *Vibrio* infections through recreational water[15].

Extreme precipitation and water pollution

Climate change also leads to more frequent extreme precipitation events, which can result in rapid runoff from surrounding areas into bathing sites. This runoff often carries contaminants such as faecal material, chemicals, and sediments from agricultural land, roads or sewer systems. As a result, the microbiological quality of the water deteriorates, often but not always indicated by increased concentrations of faecal indicator bacteria like *Escherichia coli* and enterococci.

This kind of contamination poses a direct threat to the health of bathers; gastrointestinal illnesses, respiratory urinary tract infections, and eye or ear infections may occur. The health risk increases especially after heavy rains, when combined sewer overflows lead to the discharge of untreated wastewater into natural swimming areas.

Drought and lowering water levels

Another consequence of climate change is the increased frequency and intensity of droughts, which significantly affect water levels in lakes, reservoirs, and rivers. A drop of water volume leads to higher concentrations of pollutants, decreased self-purification capacity, and overheating of shallow areas.

This results in a greater risk of cyanobacterial growth, as well as a decline in chemical and microbiological water quality. In addition, lower water levels hinder the maintenance of beaches and may endanger infrastructure (e.g., piers, entry points).

In some cases, prolonged drought may shorten or even cancel the bathing season, which has economic consequences for tourism and local governments.

Climate change is clearly and increasingly affecting bathing water quality. It introduces new challenges in terms of public health, sustainable water resource management and the need for future strategies: monitoring of early warning systems, improved wastewater treatment, restoring natural ecosystems, public awareness and education. The project CLIMRISK[16] was used for estimation of climate change impact for pilot areas in Prague, Lodz and Szentendre.

[15] https://geoportal.ecdc.europa.eu/vibriomapviewer/

[16] https://www.climrisk.eu

3.4 Tools for mitigating contamination or preventing exposure

As previously discussed, surface waters are prone to microbiological and chemical contamination from various sources. However, there remains a significant gap in the availability and application of effective tools for mitigating contamination or for preventing the exposure of bathers through early warning methods and public advice.

Mitigation measures

Measures aimed at mitigating the amount of pollution originating from stormwater and municipal wastewater in urban rivers and natural water bodies fed by these rivers can be divided into two broad categories: targeted infrastructure and source control management.

Through the construction of appropriate infrastructure, it is possible to retain sediments and pollutants before they enter river systems, increase the residence time of water in ponds and wetlands (thus reducing flow velocity and allowing sediments to settle at the bottom), and enhance infiltration (for instance, by modifying the structure of the riverbed). Another approach involves deepening the riverbed to increase the degree of sediment deposition within the water body. Source control management includes the removal of pollutants before they are washed into rivers or natural reservoirs with stormwater, for example, street cleaning to remove solid particles and metals[17].

Nature-based solutions, such as the restoration of beaver populations is highlighted as an important measure supporting the improvement of water quality and the recovery of aquatic ecosystems. Wetlands created by beavers help stabilize streamflow during drought periods and retain and slow down water flow, which promotes the sedimentation of suspended matter on the bottom of the impoundment. The bottoms of such impoundments function as pollution traps, retaining, among other substances, nutrients and heavy metals. Moreover, based on research conducted under natural conditions, it has been demonstrated that beaver habitats, despite their potential to act as a source of microbiological contamination, may in fact reduce the risk of microbiological pollution as fecal bacteria *Escherichia coli* in downstream river sections[18].

Another approach to reducing pollution in natural waters is the implementation of Best Management Practices (BMPs). This term refers to practical measures that can be applied by landowners to reduce the pollutant load transported from their land into surface waters. Such measures include, among others, the establishment of buffer zones along watercourses, the installation of fencing along riverbanks to restrict access for livestock, and the adoption of sustainable agricultural practices, for example, the use of winter cover crops and the abandonment of conventional plowing).

Artificial mixing and aeration, with air supplied to the deeper layers of the water body, can also improve the microbiological quality of water in reservoirs. The implementation of water mixing and aeration significantly alters the bacterial community structure within the ecosystem, enhances biodiversity, and

[17] Chakravarthy K, Charters F, Cochrane TA. The impact of urbanisation on New Zealand freshwater quality. Policy Quarterly. 2019 Aug;15(3):17-21.

18 White HL, Fellows R, Woodford L, Ormsby MJ, van Biervliet O, Law A, Quilliam RS, Willby NJ. The impact of beaver dams on distribution of waterborne Escherichia coli and turbidity in an agricultural landscape. Sci Total Environ. 2025 Mar 10;968:178871. doi: 10.1016/j.scitotenv.2025.178871.

leads to a notable increase in the abundance of species involved in pollutant degradation. As a result, mixing and aeration contribute to strengthening the overall stability of the ecosystem[19] .

Practical site-level measures can help improve water and beach hygiene. The WHO Guidelines on Recreational Water Safety highlights beach cleaning (or grooming) as one such tool[2]. Beach cleaning helps maintain aesthetically clean and safer recreational areas by removing litter, tar residues, and excessive algal wreck. Depending on site characteristics and available resources, cleaning can be performed mechanically (using motorized sieves dragged through the sand) or manually. While mechanical cleaning offers speed and efficiency, it can disrupt beach ecosystems and is not suitable for all locations. Examples include high-pressure cleaning to remove fuel oil contamination, which proved effective in Lebanon, and removal of nutrient-indicating macroalgae such as *Ulva* spp., which can signal pollution from nutrient enrichment. Such practices, integrated with broader risk-based water management approaches, contribute to safer, cleaner, and more sustainable bathing environments. Nevertheless, no universal solution can be applied to all sites. Each location requires tailored, context-specific measures that consider its unique hydrological, ecological, and social conditions. All interventions must comply with national and EU legislation and be designed to avoid ecological harm or disruption of natural processes, ensuring that water quality improvements are both effective and sustainable. As recreational water sites are dynamic ecosystems supporting diverse aquatic life, the protection of human health must be balanced with environmental conservation goals. Accordingly, the application of management guidelines should consider measures that safeguard both coastal and freshwater ecosystems[2].

Preventing exposure

When source mitigation or prevention of contamination is not feasible, for the protection of public health, measures should be taken to limit the exposure of bathers to contamination. The most straightforward method to do this is timely information to the public, advising them to avoid bathing in affected areas or on days when pollution is present or expected. Public information can be delivered through different platforms as locally most appropriate, including posting at the beach, on dedicated websites or through social media.

Such information to the public should be based on sound evidence derived either from same-day sampling, or predictions based on hydrological modelling, remote sensing or in situ sensors, as locally relevant or feasible. Timely public information requires good cooperation between involved stakeholders, including beach managers, public health authorities, laboratories, municipalities, water utility operators, NGO etc.

3.5 Cooperation and communication among stakeholders

Effective management of bathing waters relies on close cooperation and transparent communication among authorities, scientific institutions, NGOs, and the public. As emphasized by the WHO Guidelines for Safe Recreational Water Environments[2] and the ETC/ICM Report on the Benefits of Bathing Waters[20], such collaboration strengthens risk assessment, improves early warning systems, and builds public trust. Developing clear communication channels, promoting citizen science initiatives, and integrating public

[19] Chen F, Huang T, Wen G, Li K. Impact of artificial mixing and oxygenation on bacteria in a water transfer reservoir: Community succession and the role in water quality improvement. Sci Total Environ. 2024 Jan 15;908:168581. doi: 10.1016/j.scitotenv.2023.168581.

[20] Globevnik, L., Snoj, L., Šubelj, G., Draksler, A., McDonald, H., Thaler, T., St. John, R., 2022, Benefits of bathing waters in European cities. ETC/ICM Technical Report 04/2022: European Topic Centre on Inland, Coastal and Marine Waters, 45 pp.

feedback into water quality management can significantly improve responsiveness and compliance. In this context, cooperation between authorities, researchers, and communities not only enhances the effectiveness of monitoring and mitigation strategies but also fosters a shared sense of responsibility for maintaining healthy and resilient aquatic environments.

Public awareness of the health and environmental risks associated with water pollution is limited. Local communities may not be fully aware of the impact of pollution on water quality or the potential risks posed by pollution present in recreational water.

Some beaches lack formal regulation, leading to inconsistencies in water quality management and safety standards. These unregulated beaches pose risks to public health, especially during peak bathing season, as they may not be subject to regular water quality testing or pollution control. For example, in Osijek-Baranja County, there are a total of 4 regulated and 14 unregulated beaches. Nevertheless, most of the unregulated beaches are monitored throughout the bathing season. Upstream and downstream of the urban regulated bathing areas on the Drava River, there are some popular, wild beaches where water quality is not monitored. Supervision and raising awareness within the local community were requested for these areas. Establishing guidelines and regulations for safe bathing conditions will help mitigate health risks from waterborne pathogens and pollutants.

The Vienna Danube Canal is an urban water body connected to the River Danube. Despite not being an official bathing site, it is utilized for swimming by the Schwimmverein Donaukanal (Danube Canal Swimming Club). Consequently, the water quality of the Danube Canal is not systematically monitored with respect to established bathing water quality standards.

Limited public and local community awareness persist regarding the health and environmental risks of water pollution, particularly its impact on recreational water quality. The Vienna Danube Canal, receiving combined sewage overflow via the Wienfluss (Vienna River), is susceptible to microbiological and chemical contamination, especially following heavy rainfall.

In the Prague city area, numerous non-designated bathing waters are located on small reservoirs, ponds, sand pits, and river sections. Most standing waters (both designated and non-designated) frequently experience mass occurrences of cyanobacteria, while the rivers are suspected to be affected by faecal pollution, posing potential risks to bathers' health and recreational water quality. Addressing these challenges requires stronger cooperation and communication among stakeholders, including environmental authorities, public health institutions, local governments, NGOs, and the public. Enhanced collaboration would support coordinated monitoring, early warning, and management actions, while transparent information sharing and community engagement could improve public awareness, promote responsible behaviour, and foster joint responsibility for maintaining safe and sustainable bathing environments.

In Poland, the results of water quality monitoring for individual bathing sites are published on the website https://sk.gis.gov.pl/, that is the Bathing Service. The website features an interactive map indicating the location of bathing sites and provides daily updates on whether a given site is open for use. This platform also serves as an information exchange portal for all matters related to recreation in natural bathing waters. It functions as a comprehensive source of knowledge on cyanobacteria (blue-green algae), vibriosis, and the current legal framework governing bathing sites, including the methods and frequency of mandatory bathing water quality monitoring. In addition, the portal presents the schedule for the organization and operation of natural bathing sites in Poland, provides access to monitoring reports from 2010 to the present, and publishes official communications from the Chief Sanitary Inspector regarding bathing water quality in Poland, which are periodically issued to the public.

In Hungary, improving water quality of Danube allowed the designation of several formerly unofficial bathing sites upstream from Budapest, in the Danube Bend segment. On smaller ponds and quarry lakes, unofficial

bathing is still practiced. If a site is visited by a high number of bathers, public health authorities try to convince site proprietor to designate the bathing water or undertake the monitoring of the site. NGOs advocate for designating sites within Budapest, but there are constraints of safety and water quality.

4 Strategical goals

Based on the above considerations and the joint transnational SWOT analysis of bathing waters, five strategic goals have been formulated for safer management of urban bathing sites.

Goal 1: Improve risk identification

Risk based approach - as suggested by WHO - begins with a system assessment of bathing sites. This step includes identification of hazards and hazardous events, considering seasonal influences and predicted local climate change scenarios, as well as assessment and prioritization of risks. Current regulatory frameworks and monitoring schemes focus primarily on faecal pollution and pay limited attention to other hazards. Risk identification should be improved to address all potential hazards to human health in a site-specific manner.

Hazards to consider should include all potential sources of pollution (such as run-off, discharges, animal access), pathogens of faecal origin (e.g. *Salmonella, Campylobacter,* protozoa), autochthonous microorganisms (e.g cyanobacteria, non-toxinogenic *Vibrio* species), emerging hazards (AMR, chemical pollution). Risk identification should take into account different recreational uses, seasonal variability and climate change impacts.

UrbanBlueHealth supports achieving this strategic goal through site specific case studies on hazard identification, also incorporated into the pilot actions.

Goal 2: Improve monitoring - frequency, scope and methodology

Minimum monitoring requirements of the Bathing Water Directive (monthly monitoring of two key microbiological indicators of faecal contamination: *E. coli* and intestinal enterococci, using specified standard methods) are insufficient for reliable characterization of water quality, and subsequently, for the adequate health protection of bathers.

Monitoring scheme (including frequency, targeted parameters and methodology) should be informed by site specific risk assessment. Monitoring beyond the minimum requirement can include more frequent sampling and additional microbiological or chemical parameters. Methodological developments are necessary to overcome limitations of the current methods (e.g. long turn-around time, specificity) or for the detection of additional parameters.

UrbanBlueHealth support this goal by testing alternative methods for existing parameters and methods for the detection of additional microbiological, chemical, and molecular indicators to improve data accuracy and early risk detection. Extended monitoring scheme is also part of the pilot actions and additional case studies. The data generated through extended monitoring can be used to advocate for broader legal reforms and for the risk-based inclusion of additional parameters that reflect the full range of risks associated with waterborne diseases and pollutants and can be adapted to bathing sites aligned with the risks identified.

Goal 3: Prevent exposure to hazards including climate change impacts

The strategic goal focuses on strengthening risk management through early detection and rapid response to pollution events in bathing waters. Climate change, urban runoff, and combined sewer overflows increasingly threaten water quality, making proactive, data-driven management systems essential for protecting public health.

To support this goal, UrbanBlueHealth partner countries address this challenge through innovative monitoring and forecasting tools, develop early warning systems that integrate real-time monitoring data, predictive models, and automated alerts. These systems aim to detect pollution spikes, such as those caused by heavy rainfall or accidental discharges and provide timely information to authorities and the public. UrbanBlueHealth thus contributes to a risk-based management framework that supports faster decision-making, improves communication between institutions, and enhances overall resilience of bathing waters to environmental and climatic pressures.

Goal 4: Improve climate-resilient management and nature-based solutions

Climate change intensifies pressures on bathing water quality through rising temperatures, altered precipitation patterns, and more frequent extreme events such as floods, flashfloods and droughts. These changes exacerbate algal blooms, increase sediment and pollutant runoff, and heighten the risk of microbial and chemical contamination. Management of bathing waters needs to respond to these challenges. Nature-based solutions offer environmentally friendly opportunities to protect bathing waters from external pollution and improve water quality.

To address these challenges, UrbanBlueHealth partners are testing innovative, climate-resilient approaches that strengthen monitoring, prediction, and adaptation in different environmental and regulatory contexts.

Case examples demonstrate diverse yet complementary strategies for mitigating climate change impacts on bathing waters – combining technological innovation, nature-based design, and risk-based management to ensure safer and more sustainable recreation in a changing climate.

Goal 5: Improve cross-sectoral cooperation and communication

Effective management of urban and natural bathing waters requires strong cooperation and transparent communication among institutions, scientific bodies, public health authorities, local governments, NGOs, and citizens. To strengthen this sectoral collaboration, activities should focus on improving information exchange, data accessibility, and joint decision-making across governance levels.

UrbanBlueHealth supports this goal by case examples of cross-sectoral cooperation and information sharing in the partner countries.

5 Taking action to reach strategic goals

Meeting the strategic goals requires systematic cooperative actions. The following framework offers a roadmap to develop site-specific action plans using case examples from partner countries to illustrate potential actions under each step.

5.1 Strengthen the risk-based management framework

A comprehensive risk-based approach, consistent with WHO's Recreational Water Safety Plan (RWSP) (WHO, 2023) framework, should become the foundation of bathing water management. This includes the systematic identification of hazards, risk assessment, and the implementation of control and response measures.

Key actions

- Identify site-specific hazards (microbiological, chemical, and environmental) considering local hydrology, catchment characteristics, and climate scenarios.
- Conduct risk assessments for each designated and potential bathing site, including non-designated areas under high public use.
- Develop and implement site-level RWSPs defining responsibilities, operational limits, and response protocols for pollution events. The risk-based framework recommended by WHO creates an opportunity to tackle locally relevant risks in a site-specific manner.

Expected outcomes: Early identification of risks, improved preparedness, and harmonized risk-based management across partner countries.

Case examples

Autochthonous microorganisms - non-cholera Vibrio

Climate change is increasingly recognised as a key driver in the spread of waterborne infectious diseases caused by bacterial pathogens. Among these, *Vibrio* species including *Vibrio vulnificus, Vibrio parahaemolyticus* and non-toxinogenic Vibrio cholerae are of particular concern due to their ability to thrive in warm, low-salinity waters. Their abundance leads to more frequent human infections and outbreaks, especially after extreme weather events. Since *Vibrio* growth is strongly temperature dependent, these bacteria serve as a indicator of climate change impacts on aquatic ecosystems.

As part of efforts to identify emerging hazards in bathing waters, during the 2024 bathing season an assessment of non-toxinogenic *Vibrio* was conduction in natural bathing sites of Hungary. In 96% of the samples, non-toxigenic *Vibrio cholerae* strains were detected in shallow lakes, with colony counts exceeding 100 CFU/100 ml in 73 % of analysed samples. The findings provided valuable baseline data and supports the need to test new monitoring methods and perform further analyses of emerging hazards such as vibrios.

Complex approach to microbiological and chemical hazards

Salmonella is a pathogenic microorganism capable of causing severe gastroenteritis in humans, with infections triggered by very low doses. It can enter surface waters via wastewater discharges, agricultural runoff, or animals and birds, posing significant health risk for bathers.

Somatic coliphages, viruses that infect coliform bacteria, are increasingly recognized as reliable viral indicators of faecal contamination, particularly where bacterial indicators may underestimate risks. Scientific studies have shown correlations between Salmonella, somatic coliphages, and conventional bacterial indicators, underscoring their potential value as additional parameters in bathing water monitoring to better protect public health.

Pharmaceutical residues, such as antibiotics, hormones, and painkillers, are increasingly detected in rivers and lakes due to wastewater discharges, agricultural runoff, and improper disposal. Most treatment plants cannot fully remove these compounds, which may persist in the environment and pose risks to ecosystems and human health. Antibiotics, for example, can promote antimicrobial resistance, while hormones disrupt aquatic organisms. Although concentrations found in bathing waters are often low, the effects of long-term exposure remain uncertain, especially for vulnerable groups like children and the elderly. Since current legislation does not cover pharmaceuticals, systematic monitoring is lacking. The case study of Croatia on the Drava River will therefore include pharmaceutical measurements to fill this gap, improve understanding of their presence in bathing waters, and support future risk assessments and management strategies. Parallel measurements of physicochemical parameters, such as pH, turbidity, conductivity, nitrogen, will also be carried out to support comprehensive water quality evaluation.

Antimicrobial resistance

Monitoring of antimicrobial resistance (AMR) in bathing water is part of a broader One Health approach, addressing the interconnectedness of human, animal, and environmental health. The main goal of the corresponding investigations in Hungary and Poland is to improve understanding of how recreational waters contribute to the spread of antibiotic-resistant bacteria (ARB) and antibiotic resistance genes (ARGs), and to explore feasibility of incorporating AMR indicators into routine water quality assessments. Antimicrobial resistance is an escalating global problem, driven by the extensive use of antibiotics in medicine and agriculture. Residual antibiotics and resistant microorganisms enter aquatic environments through wastewater discharges, agricultural runoff, and animal waste, where they accumulate and promote the selection and persistence of resistant strains.

5.2 Expand scope and improve monitoring methodology

Monitoring of bathing waters is currently limited to *E. coli* and intestinal enterococci, with low sampling frequency and long analytical turnaround times. These limitations prevent timely detection of contamination and emerging health risks.

Key actions:

- Broaden the scope of monitoring programs to include additional locally relevant indicators, based on the outcomes of risk assessment. Additional indicators can include cyanobacteria, enteric pathogens, autochthonous pathogens or hazardous chemicals, among others.
- Consider monitoring sand or sediment for faecal indicators or other parameters
- Introduce rapid and automated methods (e.g., ß-glucuronidase activity sensors, Bluephage test, rapid molecular assays) to complement standardized ISO reference methods, where relevant.
- Introduce low-cost sensor networks linked to open dashboards

Expected outcomes: Faster, more comprehensive detection of contamination events; improved evidence base for decision-making; and enhanced protection of public health.

Case examples

Introducing novel monitoring approaches

The case study of Czechia focuses on improving the understanding and monitoring of microbiological risks in flowing river waters, particularly within the urban area of Prague. The main goal is to test new methodologies and expand the range of monitored microbiological parameters to support evidence-based designation and management of urban bathing sites.

Extended microbiological monitoring is introduced, focusing on opportunistic and anaerobic pathogens such as *Campylobacter* spp., *Clostridium perfringens*, *Acinetobacter* spp., and *Leptospira* spp. to better capture health-relevant risks not covered by current EU legislation. Additionally, alternative analytical methods are tested (e.g. TBX for *E. coli* and Enterolert DW for enterococci) for faster and more reliable bathing water assessment.

Rapid indicators of microbial water quality

The case study in Austria focuses on enhancing bathing water quality monitoring through the inclusion of additional microbiological and physicochemical parameters, as well as the development of improved analytical methods for faster and more reliable detection of faecal contamination. The main objective is to assess the potential of *E. coli*-specific ß-glucuronidase activity as a rapid indicator of microbial contamination in natural bathing waters. In addition to the parameters prescribed by national and EU legislation (*E. coli* and intestinal *Enterococci*), monitoring covers *Pseudomonas aeruginosa*, *Clostridium perfringens*, and somatic coliphages, which provide a broader picture of waterborne pathogens and faecal contamination sources. Parallel measurements of physicochemical parameters, such as pH, turbidity, conductivity, and UV transmission support comprehensive water quality evaluation. By integrating enzymatic activity monitoring into standard bathing water assessments, analysis time can be shortened and, early warning capabilities improved. These analyses support the transition toward risk-based water quality management, ensuring better protection of public health and bathing water safety.

5.3 Integrate climate adaptation into bathing water management

Climate change is expected to intensify hydrological variability, algal blooms, and pathogen spread in recreational waters. Current monitoring and management frameworks are not yet fully adapted to these emerging pressures.

Key actions

- Use predictive modelling and meteorological data to forecast weather-related pollution risks, supported by local early warning systems.
- Implement satellite-based remote sensing (e.g., Sentinel-2) for high-frequency monitoring of algal blooms and phytoplankton dynamics.
- Incorporate climate risk scenarios into RWSPs and management plans.
- Introduce temporary bathing bans based on pre-defined thresholds for extreme weather events (e.g. storms or flash floods).
- Incorporate climate projections into long-term water management plans.

Expected outcomes: Improved resilience of bathing waters to extreme weather, reduced frequency of algal blooms, and strengthened preparedness for climate-induced health risks.

Case examples

Early warning using forecasting models for weather-related pollution risk

To strengthen preparedness and ensure timely responses to sudden changes in water quality, an early warning system is being developed for the Drava River bathing sites in Osijek, Croatia. The system combines continuous online monitoring, real-time data collection, and predictive modelling to identify pollution risks such as those from heavy rainfall, stormwater inflow, or accidental discharges before they impact public health. Using data from multiparameter sondes, weather stations, and laboratory analyses, predictive models were built to enhance forecast accuracy and guide rapid management actions, including temporary beach closures or health advisories.

Monitoring scheme is being expanded to include climate-related parameters such as rainfall intensity and water level fluctuations at Osijek's urban beaches. By integrating real-time alerts and forecasting tools, the system aims to detect short-term pollution events often missed by traditional sampling, enabling faster responses and improving public safety. In the context of climate change, which is expected to intensify floods, droughts, and algal blooms while also fostering pathogen growth, this approach provides a comprehensive and adaptive framework for managing bathing water quality.

Early warning system using rapid testing methods

The early warning system for the Danube Canal in Vienna aims identify reliable proxy indicators that can predict contamination events and support real-time risk management. Continuous, high-frequency

monitoring of *E. coli* enzyme ß-glucuronidase activity is performed using automated systems to capture short-term contamination peaks.

Weather-related data (precipitation, water levels in the Danube and Danube Canal) are incorporated to establish links between rainfall events, hydrological changes, and water quality deterioration. With climate change expected to increase extreme events and non-point source pollution, this integrated dataset supports the development of predictive models capable of issuing early warnings for pollution spikes, such as those following combined sewer overflows. The case study demonstrates how real-time monitoring and predictive modelling can form a robust early warning framework, enabling rapid communication to authorities and bathers, preventing exposure to contaminated water, and strengthening resilience against the growing impacts of climate variability.

Satellite imaging in water quality assessment

In Czechia, satellite imaging is used as an innovative tool for bathing water monitoring. This method provides faster and higher spatial resolution data on phytoplankton distribution and can function as an early warning system for algal blooms. By providing more comprehensive and timely information to laboratories, public health authorities, and water management institutions, satellite imaging contributes to better-informed decisions and stronger protection of public health in the context of climate-driven water quality challenges.

5.4 Apply practical tools for contamination mitigation

Preventive and corrective measures are essential to maintaining safe bathing conditions, particularly in urban or high-use environments. WHO guidelines recommend integrating environmental protection tools that minimize contamination sources while safeguarding natural ecosystems.

Key actions

- Adopt site-specific mitigation measures such as aeration, sediment management, and improved stormwater control.
- Implement beach cleaning programs (mechanical or manual) that balance hygiene benefits with ecosystem preservation.
- Ensure that all interventions comply with environmental legislation and avoid ecological harm or disruption of natural processes.
- Encourage pilot testing of innovative water treatment solutions and evaluate their scalability under local conditions.
- Apply nature-based and adaptive technologies (e.g., aeration systems, vegetated buffer zones, constructed wetlands) to enhance water self-purification capacity. Design adaptable bathing sites (e.g. floating pontoons, shaded zones, vegetation buffers).
- Improve flood resilience with permeable surfaces, rain gardens, and green belts.
- Develop buffer zones (vegetation, barriers) to reduce runoff impacts.
- Monitor illegal discharges with enforcement tools (e.g. drone surveillance, reporting apps).

Expected outcomes: Cleaner, safer bathing environments and more sustainable, ecologically balanced site management.

Case examples

Nature based water treatment

In Łódź, Poland nature-based water treatment is used to enhance bathing water safety and resilience to climate change. Stefański Ponds, a designated bathing area fed by two small rivers, faces significant pollution pressures from municipal wastewater discharges and agricultural runoff, leading to chemical and biological contamination, frequent algal blooms, and reduced ecosystem self-purification capacity.

To address these challenges, aeration was selected as a nature-based intervention to increase oxygen levels in deeper water layers and restore ecological balance. The device design was tailored to local conditions, including pond depth, sediment accumulation, and inflow dynamics, ensuring optimal performance and environmental compatibility. The intervention is coupled with continuous water quality monitoring covering physical, chemical, and biological parameters is used to evaluate aeration efficiency. Together, these integrated measures promote proactive risk management and climate adaptation, offering a replicable model for improving water quality, reducing algal blooms, and safeguarding public health in urban bathing sites.

Installing a storm water reservoir

In Szentendre, Hungary a natural stream and discharge from the local wastewater treatment plant were identified as major pollution sources, while pollution events were associated with extreme precipitation. To reduce untreated sewage discharge, a stormwater reservoir was established at the wastewater treatment plant (WWTP) to mitigate the impacts of combined sewage overflow events during periods of heavy precipitation. The reservoir can store sewage diluted with precipitation before entering the WWTP. This prevents untreated sewage discharge into the river and allows the polluted water to be treated over a longer period of time after the extreme precipitation.

5.5 Strengthen cooperation, communication, and public engagement

Fragmented governance and limited awareness undermine effective bathing water management. Enhanced cooperation among institutions, beach operators, NGOs, and the public is essential for achieving long-term improvements.

Key actions

- Establish national and local Bathing Water Working Groups to coordinate stakeholders from public health, environmental, and water sectors.
- Promote collaboration with NGOs and community organizations to raise awareness and promote responsible behaviour.
- Implement targeted education and awareness raising campaigns, including signage, workshops, and online platforms, to inform citizens about safe bathing practices and water quality updates.

- Support transparency through real-time public access to monitoring data via online platforms and mobile applications.
- Strengthen institutional capacity through training and intersectoral coordination between health, environment, and water management authorities.
- Improve data comparability and accessibility through regional platforms, joint databases, and open data sharing among authorities and laboratories.

Expected outcomes: Increased public trust, stronger intersectoral cooperation, and shared responsibility for water safety across all stakeholder groups.

Case examples

Communication with stakeholders

In UrbanBlueHealth, all partner countries established national Bathing Water Groups comprising representatives from public health authorities, environmental agencies, local governments, research institutions, NGOs, and bathing site operators. These groups serve as national coordination platforms to facilitate dialogue, exchange knowledge, and align actions related to bathing water management and public health protection. Bathing Water Groups meet regularly (in person or online) to discuss national challenges, priorities and solutions.

Working with NGO's

In Austria, collaboration with civil society has played a key role in promoting sustainable urban bathing practices and community engagement. One notable example is the partnership with the "Schwimmverein Donaukanal" (Danube Canal Swimming Club), a non-profit cultural association founded in 2020 by a collective of social designers from *die Angewandte* (University of Applied Arts Vienna). Originally emerging as an artistic initiative during the pandemic, the association has since evolved into a vibrant community movement dedicated to reviving and promoting urban swimming culture in Vienna's Danube Canal. Today, the Schwimmverein Donaukanal has over 300 active members and collaborates with a wide range of stakeholders, city institutions, and international initiatives focused on sustainable water use, public space revitalization, and environmental health.

Within the UrbanBlueHealth project, the association played a crucial role in bridging science, governance, and the public, using creative communication formats and awareness campaigns to inform citizens about the relationship between water quality, climate change, and public health. This collaboration demonstrates how partnerships with NGOs can strengthen outreach, foster community participation, and promote long-term behavioural and policy changes for safer and healthier urban bathing environments.

Public engagement and awareness

Many citizens continue to use unregulated bathing sites where water quality is not systematically controlled, creating additional public health risks. Climate change further amplifies these risks, as rising temperatures, shifting rainfall patterns, and more frequent floods or droughts create conditions for harmful algal blooms, sediment and pollutant runoff, and the spread of water transmissible pathogenic bacteria, viruses and

parasites. To address these challenges, public engagement and awareness campaigns are essential. Informing communities about safe bathing practices, potential health risks, and the importance of water quality monitoring empowers citizens to make safer choices and support sustainable water management. Educational initiatives (such as local information boards, mobile applications, and citizen science activities) can further strengthen community participation and promote shared responsibility for maintaining clean and healthy bathing environments.

In Czechia, public engagement has been an essential component of the internet based self-reporting questionnaire, which has been active since 2009 and has been particularly useful for identifying outbreaks of cercarial dermatitis. The questionnaire, containing question related to the occurrence of illness after bathing, has been regularly promoted through websites providing information on bathing water quality.

In Croatia, education is considered a key tool for improving bathing water safety and sustainable management. Using data-driven insights, it supports better monitoring strategies and targeted awareness campaigns focused on unregulated bathing sites. Through workshops, information boards, and online communication, citizens are informed about health risks, responsible behaviour, and the importance of water quality monitoring. This community engagement fosters long-term behavioural change, empowering residents to make informed choices and supporting the broader UrbanBlueHealth goals of safer and more sustainable recreation.