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ABSTRACT

This joint policy brief of the ZeroPollution4water cluster aims to stress and seek feedback on initiatives from seven EU funded projects (NINFA, SafeCrew, Mar2Protect, H2OforALL, ToDrinQ, UPwater, and intoDBP) dedicated to protecting surface and groundwater resources, ensuring drinking water safety, and supporting other applications. The document will be updated regularly by the cluster in order to incorporate the new outcomes of the projects and disseminate across different channels at the EU level.

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INTRODUCTION

This policy brief represents a collaborative effort conducted within the ZeroPollution4water cluster's policy working group. Its purpose is to showcase and solicit feedback on the various initiatives under seven EU-sponsored projects aimed at safeguarding surface and groundwater resources, ensuring the safety of drinking water, and supporting other applications. The projects in focus are NINFA, SafeCrew, Mar2Protect, H20forALL, ToDrinQ, UPwater, and intoDBP, all of which are in progress. Consequently, the deliverable D.7.4 has been delayed in order to produce and agree on this document between the seven projects.

The brief is structured in two sections: the first highlights the contributions of each project to the Zero-Pollution Strategy, while the second offers preliminary findings from the intoDBP and H2OforAll projects. The first part is mainly a presentation of the expected outcomes of the different projects and the possible synergies in the future.

In the second part of the policy brief, intoDBP played a significant role, working closely with H2OforAll, as these projects are at the forefront in terms of delivering public outcomes. The main recommendation is:

- Adopt management strategies and tools (e.g. DSS), based on detailed knowledge of groundwater resources uses and renewal rate, to effectively mitigate the effects of climate change (with special focus on drought and extreme events)

The recommendations extracted from the first deliverables of intoDBP and H2OforAll are:

- Develop a flexible regulatory framework for DBPs including iodinated and nitrogen containing DBPs (I-DBPs and N-DBPs).
- Safety Data Sheet – accessibility of information and better coverage.
- Invest in R&I projects to develop cost-effective technologies for real-time data acquisition and removal of micropollutants, pathogens and DBPs.
- Gain better knowledge about the situation and impact of new Contaminants of Emerging Concern (CEC) (e.g. through mapping) in terms of social aspects and potential policy measures to take.
- Incorporate in future R&I calls: living labs, strong training and awareness-raising programmes for society and all stakeholders particularly focused on CECs.
- Clarify and improve data requirements and management, particularly regarding the identification and monitoring of different antibiotic resistant genes (ARG's) and their impact on health.
- Invest in drinking water infrastructures, their design and operation to improve the resilience of our system.
- Improve the planification of wastewater reuse at basin level, including with aquifer recharge.
- Support biobased and nature-based mitigation solutions with a risk assessment.
- Minimise the pollution of micropollutants, including microplastics, pathogens and DBPs in the drinking water networks.

The dissemination of this policy brief will be a collaborative effort involving all seven projects, utilizing a common design from the cluster. Target audiences will primarily include various European expert groups, such as the Zero Pollution Stakeholder Platform, the EU Drinking Water, and Groundwater Expert Groups, among others. Additionally, the dissemination efforts will extend to other networks like the WE Working Group on Zero-Pollution, ICT4water Cluster, Water4all, UNWWQA, Eureau, APE, EWA, as well as local authorities and European policymakers, although not exclusively.

Finally, this policy brief is designed as a dynamic document, intended to be updated regularly to reflect new results and recommendations from the various projects.

1. Policy brief: Preventing groundwater contamination and securing drinking water quality

This policy brief aims to present and gather inputs from the different activities of the seven EU-funded projects related to the protection of surface and groundwater, to safe drinking water provisions and other uses. The projects are: NINFA, SafeCrew, Mar2Protect, H20forALL, ToDrinQ, UPwater, intoDBP. It is built upon the first cluster meeting organised in October 2023 in Brussels[1].

The policy brief is composed of two parts: the first one lists the benefits of each project for the Zero-Pollution Strategy, and the second one compiles the first insights from the intoDBP and H2OforAll projects.

1.1 The Cluster

The ZeroPollution4Water cluster is an initiative originating from the coalition of seven different projects (see annex I) funded from two Horizon Europe 2022 calls which aim to:

Prevent groundwater contamination and protect its quality against harmful impacts of global and climate change.

secure drinking water quality by protecting water sources against pollution, providing innovative monitoring and treatment solutions, and ensuring safe drinking water distribution.

Focusing on the European Union's zero-pollution ambition and the European Green Deal, the cluster aims to leverage the cooperation and synergies among these seven projects to develop advanced prevention and mitigation strategies, effective risk assessment and management systems, and innovative monitoring and treatment solutions for drinking water and groundwater management. It also aims to develop new technologies ready for the market to prevent or tackle water pollution.

1.2 Responding to the challenges of diffuse pollution of surface and groundwater

This cluster aims to unite efforts towards enhancing the prevention of surface and groundwater pollution, ultimately contributing to the development of Water-Smart Societies. Diffuse pollution remains a significant pressure, affecting 35% of the EU's groundwater bodies, while quality standards for substances like pesticides and herbicides are exceeded in 15% of the studied groundwater bodies[2]. Moreover, climate change exacerbates pressure on groundwater quality, by reducing aquifer recharge and related resources, as well as by triggering additional withdrawals.

[1] Water Project Europe 2023, ZeroPollution4Water Cluster, 19 October 2023, Brussels.
[2] https://cordis.europa.eu/programme/id/HORIZON_HORIZON-CL6-2022-ZEROPOLLUTION-01-01

In its outlook of drought policies, the EU Commission stresses the increasing challenge of water scarcity in Europe and the need to improve drought management, including the protection of drinking water sources[3]. As 65% of drinking water in Europe is supplied by groundwater bodies [4], it is paramount to protect these sources against pollution and pressures.

In May 2021, the EU Commission adopted the Zero Pollution Action plan (ZPAP), a key milestone of the European Green Deal. This plan addresses air, water, and soil pollution, aiming to reduce them to levels no longer considered harmful to health and natural ecosystems, while also respecting the planet's boundaries. The goal is to create a toxic-free environment by 2050. To accelerate pollution reduction, the plan includes binding intermediate targets to achieve substantial reduction in pollution at the source by 2030.

Additionally, the behavior of microplastic particles (MPPs) and their presence in drinking water is of major importance due to their universal and daily consumption. As part of the effort to enhance water quality, the Plan's targets also include reducing plastic litter at sea by 50%, as well as reducing microplastics released into the environment by 30%. This is particularly relevant in countries where desalination plants are on the rise.

The main question is: *How can the water sector and water-related activities adopt and implement the Zero-Pollution Strategy?*

1.3 Contributing to the Zero Pollution Strategy and the implementation of the water-related legislation

This Cluster supports the implementation of the updated Water Acquis and other EU water-related directives. The EU Commission has developed diverse policies such as the ZPAP under the Green Deal. Rather than introducing new requirements that involve developing new standards and actions, the EU Commission views the ZPAP as a 'unifying call to action' for practitioners, especially policy makers to synergize the revision of related legislation and its implementation. The ZPAP is a tool to align actions to develop and deliver an ambitious and yet practical agenda to reduce pollutant emissions into the environment. Existing EU legislations are key mechanisms for delivering the objectives of the ZPAP.

The European institutions have also launched a major revision of the water-related Acquis Communautaire:

- The Water Framework Directive (WFD) and particularly the Environmental Quality Standards Directive EQSD) and Groundwater Directive (GWD)
- the Drinking Water Directive,(DWD)
- the Urban Wastewater Treatment Directive (UWWTD)

[3] European Commission. Directorate General for Environment., *Stock-Taking Analysis and Outlook of Drought Policies, Planning and Management in EU Member States: Final Report.* (LU: Publications Office, 2023), https://data.europa.eu/doi/10.2779/21928.
[4] European commission, *water, groundwater,* Brussels. https://environment.ec.europa.eu/topics/water/groundwater_en

Box- Towards a Zero-Pollution Strategy for Contaminants of Emerging Concern in the Urban Water Cycle

In 2022, the Zero Pollution Working group released a white paper *Towards a Zero-Pollution Strategy for Contaminants of Emerging Concern in the Urban Water Cycle*. The main recommendations are:

- Achieving the EU's ambition of zero pollution requires the elaboration of policies that address the effects of pollution mixtures on public health and ecosystems. These policies should be built upon comprehensive data about exposure to pollutants, considering variations in time and place, and their effects on human and ecosystem health.
- Achieving a zero-pollution environment calls for a combination of 'at-source' measures and the removal of compounds during water and wastewater treatment. Lowering emission at-source can be achieved by reducing the production volume and use of harmful chemicals. This should be enabled by extending the registration of chemicals, including their production volumes.
- A broader classification into different groups of chemicals, based on their toxicity and use, is needed to support the development of regulations. Environmental quality standards are required for prioritised pollutants in water bodies. To enforce these standards, smart monitoring policies must be developed and implemented.
- Many urban discharges to receiving waters, including urban stormwater runoff, combined sewer overflows and unplanned discharges, remain unregulated. Incentives for tackling pollution from these unregulated flows are needed and can be created by including them in future regulations. Improving governance processes to support and optimise stakeholder activities is also needed to achieve a zero-pollution environment.
- Stimulating investments from public and private actors to restore the natural functions of groundwater, surface water, and marine and coastal waters in a systemic way.

In this context, the "zero" in ZPAP is political rather than science-driven, implying the need to continually strive to further reduce emissions. However, the need for zero pollution activities to consider feasibility / economics of potential measures is recognised in alignment with, for example, the use of Best Available Technology (BAT).

Moreover, the cluster will be keen to provide recommendations on Managed Aquifer Recharge (MAR). Current legislation does not prevent the possibility of offering aquifers with reused water or water from rivers. Indeed, recharging aquifers is a necessary tool to combat hydric stress, and in certain cases where the watersheds bring pollutants, it can also be beneficial in reducing pollution concentration in aquifers.

This cluster can also play an important role in the ongoing review of the Nitrates Directive, and Sewage Sludge Directive. These directives aim to reduce nitrate pollution from agricultural activities. Nitrate pollution, particularly in groundwater, is far from being controlled and is also causing negative impacts on several water sources used for water supply.

Lastly, the European Union is now working on the Water Resilience Initiative. This initiative aims to build a state-of-the-art framework for water management in Europe. Research and Innovation at various levels, including technological and non-technological approaches (e.g. legislative, planning, governance, institutional, participatory approaches) are key to providing solutions and support several objectives of the European Union, including tackling pollution[5]. The cluster can therefore make a significant contribution to this initiative, particularly by enhancing the resilience of the water cycle and fostering related research and innovation activities (cf. annex II).

The source protection for drinking water supply is particularly relevant for several European expert groups (e.g. Zero pollution stakeholder platform, EU drinking water, groundwater expert groups), other networks (e.g. WE working group on zero-pollution, ICT4water cluster, Water4all, UNWWQA, Eureau, APE, EWA), as well as for local authorities and European policy-makers.

This policy brief is a living document that will be periodically revised to incorporate the new outcomes of the different projects and recommendations.

Due to the confidentiality of some of the data, the projects might not disclose information that confirm or will confirm some recommendations. The projects can be contacted via loic.charpentier@watereurope.eu to obtain the relevant contact and information in the respect of this confidentiality framework.

Recommendations
• Adopt management strategies and tools (e.g. DSS), based on detailed knowledge of groundwater resources uses and renewal rate, to effectively mitigate the effects of climate change (with special focus on drought and extreme events) **Recommendation extracted from the first deliverables of intoDBP and H2OforAll (c.f. part II):** • Develop a flexible regulatory framework for DBPs including iodinated and nitrogen containing DBPs (I-DBPs and N-DBPs). • Safety Data Sheet – accessibility of information and better coverage. • Invest in R&I projects to develop cost-effective technologies for real-time data acquisition and removal of micropollutants, pathogens and DBPs.

[5] European Commission. Directorate General for Research and Innovation., *Horizon Projects Supporting the Zero Pollution Action Plan*. (LU: Publications Office, 2022), https://data.europa.eu/doi/10.2777/87880.

- Gain better knowledge about the situation and impact of new Contaminants of Emerging Concern (CEC) (e.g. through mapping) in terms of social aspects and potential policy measures to take.
- Incorporate in future R&I calls: living labs, strong training and awareness-raising programmes for society and all stakeholders particularly focused on CECs.
- Clarify and improve data requirements and management, particularly regarding the identification and monitoring of different antibiotic resistant genes (ARG's) and their impact on health.
- Invest in drinking water infrastructures, their design and operation to improve the resilience of our system.
- Improve the planification of wastewater reuse at basin level, including with aquifer recharge.
- Support biobased and nature-based mitigation solutions with a risk assessment.
- Minimise the pollution of micropollutants, including microplastics, pathogens and DBPs in the drinking water networks.

2. PART I: The EU projects involved in the ZeroPollution4Water Cluster

List of projects described below: NINFA, SafeCREW, Mar2Protect, H20forALL, ToDrinQ, UPwater, intoDBP.

NINFA

TakiNg actIoN to prevent and mitigate pollution oF groundwAter bodies)

The NINFA project deals with groundwater (GW) management solutions in the context of global and climate change. Contaminants like pharmaceuticals (CEC), antibiotic resistance genes (ARG), hydrocarbons, heavy metals, and microplastics (MP) infiltrate GW from sources, such as wastewater treatment plants (WWTPs) and urban runoff during storms, are impacting interconnected water bodies like rivers, wetlands, and oceans. Although efforts exist to monitor and protect GW, gaps remain in understanding cumulative stressors and developing cost-effective monitoring and decision-making tools for sustainable governance and management. Addressing these challenges is crucial for safeguarding GW quality and resilience in the face of ongoing environmental changes. NINFA overall goals:

- Developing cost-effective groundwater modelling and monitoring strategies
- Test cost-effective pollution prevention and abatement technologies,

- Create a holistic Decision Support System (DSS) with integrated early warning mechanisms.

Benefits of the project
• Development of cost-effective monitoring strategies and water treatment trains of technology • Creation of a digital platform (NINFA Platform) with a Decision Support System (DSS) which contains all information related to modelling, risk assessment, monitoring, prevention, and management of GW. • Development of integrated tools for water resource management optimization and climate change mitigation. •

Contribution to the ZeroPollution4Water Cluster

- Test different approaches from very different case studies (The Netherlands, Spain, France, Egypt, Mexico, and Colombia)
- Develop knowledge on a holistic GW platform that combines modelling, risk analysis, monitoring, mitigation technology and a user-oriented Decision Support System.

SafeCREW

Climate-resilient management for safe disinfected and non-disinfected water supply systems

The SafeCREW project deals with management solutions for water supply systems with and without disinfection in the context of climate change. This includes analytics (both regulated and novel disinfection by-products (DBPs), natural organic matter (NOM), toxicity, interaction with materials), water treatment (removal of DBPs and selectively NOM as DBP precursors), online monitoring (trihalomethanes (THMs), selective and rapid detection of microorganisms) and management strategies (risk management, modelling, guidelines). This project aims to guarantee safe drinking water despite climate change impact by:

- Full seasonal monitoring of microbial and chemical parameters, which will be performed in source waters from surface water and bank filtration sites to conduct reliable risk management and derive the minimum disinfection requirements.
- A combined risk management approach for microbial, chemical, and toxicological risks, which will be developed using novel tools (online THM sensor, novel DBP analysis, identification of DBP-NOM precursors) as well as virtual tools (soft sensors, modelling).

Benefits of the project
• Generate advanced knowledge to provide input to the implementation and future revisions of the EU Drinking Water Directive (DWD) and its associated watch lists (e.g. emerging substances, consideration of relevant new DBPs) • Provide inputs for the certification of materials in contact with water as stressed for future progress regarding article 11 DWD. • Develop, apply, and promote the use of integrated risk-based approaches for optimal drinking water supply systems (DWSS) management, in line with DWD articles 7-8. • Increase the preparedness of the EU drinking water sector towards water quality challenges by providing novel monitoring, modelling, and treatment approaches to minimise the exposure of DW consumers to DBPs.

Contribution to the ZeroPollution4Water Cluster

- Test new analytical and treatment approaches at different case studies sites (Germany, Italy, Spain)
- Identify precursor NOM compounds for regulated and relevant non-regulated DBPs, and develop passive sampling methods.
- Clarify polymer lining materials interaction in drinking water distribution with disinfectants and DBPs.
- Develop knowledge on occurrence, persistence, toxicity, and removal of regulated and currently non-regulated DBPs.

MAR2PROTECT

Preventing groundwater contamination related to global and climate change through a holistic approach on managed aquifer recharge.

MAR2PROTECT (M2P) will provide a holistic approach to preventing groundwater contamination from the impacts of global change and climate change, based on a new-generation Managed Aquifer Recharge, tested in seven cases studies in Europe and Beyond. The core of this innovative Managed Aquifer Recharge is M-AI-R Decision Support System that will incorporate technological and societal engagement information using an Artificial Intelligence-based approach to improve groundwater quality and quantity. M2P project overall goals:

- Prevent Managed Aquifer Recharge-related groundwater contamination.
- Prevent groundwater diffuse pollution from agriculture.
- Develop and validate innovative real-time integrated sensing systems and innovative analytical methods for the monitoring of pollutants, generating a better understanding of pollution sources and pathways in groundwater.

- Predict the impacts of global and climate change on groundwater quality in a specific context.
- Develop groundwater management strategies through the development of a Decision Support System, based on Artificial Intelligence techniques.
- Increase the active role of societal actors in the prevention of water contamination and managing groundwater.
- Facilitate the use of the MAR2PROTECT results (solutions, scientific and policy insights) by scientists, authorities, technology developers and policymakers in the prevention of water contamination and in groundwater management.
- Promote the market uptake of technologies and societal engagement actions by end users.

Benefits of the project
• Provide tailored advice and recommendations to the project members at each demo site based on an analysis of the policy landscape and options that regulate and enable actions, at the local and national levels. • Provide recommendation on the implementation and revision of the Ground water directive and its list of contaminants. • Demonstrate both technical and non-technical solutions to provide best practices for the implementation of the aforementioned directives. • Develop an innovative Living Lab methodology and approach to encourage inclusive governance and enhance the proactive role of civil society in the prevention of water contamination and groundwater management.

Contribution to the Zero Pollution4Water Cluster

- Develop nine technologies for the removal and subsequent (bio)degradation of salinity and emerging micropollutants from wastewater and surface water before their use for Managed Aquifer Recharge. These technologies aim to achieve a >95% removal and >70 % (bio)degradation of pharmaceuticals, pesticides, perfluorinated alkyl substances, nutrients, and salinity.
- Co-develop policy recommendations within the cluster activities.

H2OforAll

Innovative Integrated Tools and Technologies to Protect and Treat Drinking Water from Disinfection By-products (DBPs)

The H2OforAll project focuses on disinfection by-products (DBPs) that result from the interaction of disinfectants like chlorine with natural organic materials in water. It aims to:

- Understand & monitor disinfection by-products (DBPs) and their spread through drinking water distribution systems.

- Develop breakthrough water treatments to remove DBPs or avoid their formation during water disinfection processes, paying attention to their life cycle analysis, costs, and risks.
- Establish preventive measures for water protection engaging public and stakeholders.

Benefits of the project
• Foster protection of the EU drinking water supply chain quality for safe human use via a better understanding of DBPs toxicity and environmental impact • Better prevention of DBPs formation via water treatments and digital monitoring tools. More information included in the annex

Contribution to the ZeroPollution4Water Cluster:

- Sensors (combining spectroscopy with auxiliary sensors to monitor water quality)
- Sensing infrastructure with real time monitoring capabilities and intelligently place in the water distribution network.
- Modelling considering the topology, topography, water consumptions, type of materials, age – case-study Águas de Coimbra.
- Better understanding and assessment of DBPs formation and evolution
- DBPs toxicity and risk assessment using multi-criteria decision-making techniques.

ToDrinQ

TOolkit for aDaptable, Resilient INstallations securing high Quality drinking water

The ToDrinQ project addresses the impact of climate change and increased pollution on drinking water quality. The project will support evidence-based treatment plant design and enhance operational awareness and response in the overall water system. The overall objectives of ToDrinQ are:

- Support the implementation of the revised drinking water directive.
- Enhance scientific and technical knowledge on drinking water quality protection, monitoring, and treatment.
- Increase the resilience of drinking water systems in terms of both increased robustness and adaptability.
- Ensure high-quality drinking water, minimising the concentration of (in)organic micropollutants, pathogenic micro-organisms and disinfection by-products (DBPs).

Benefits of the project

- Contribute to a better implementation of the new drinking water directive, especially related to risk-based management.
- Develop real-time monitoring strategies for early warning on pollution and rapid interventions in drinking water supply.
- Develop new treatment processes for removal of organic matter and organic micropollutants.
- Develop decision support systems for better design and operation of drinking water supply.
- Raise awareness and provide recommendation to the water utilities and the local and European policy makers to improve drinking water system.
- Adopt solutions and technologies to enhance competitiveness of the EU water sector and increase the EU's position and role in the global water scene.
- Contribute to the EU Green Deal and the UN Sustainable Development Goal 6.\

Contribution to the ZeroPollution4Water Cluster

- Provide new solutions and technologies to reach the objective set up by the call of proposals for these research projects.
- Provide new knowledge to minimize the formation of disinfection by-products (DBPs) in drinking water.
- Provide recommendations to EU and local policymakers to improve the implementation of the relevant European legislation.
- Raise awareness and provide information on advanced and cost-effective drinking water treatment, including disinfection processes and process operation.

UPwater

Understanding groundwater Pollution to protect and enhance WATER quality

The UPWATER project addresses the widespread issue of groundwater pollution by identifying effective regulatory and legislative preventive measures and developing cost-efficient methods to measure pollutants, identify their sources and to mitigate the pollution. UPWATER aims to:

- Validate these methods in three case studies in different EU climates.
- Develop hydrogeological models for decision-making scenarios, considering multiple stressors and climate change projections.
- Adopt preventive measures, scale-up bio-based solutions, and update chemical priority lists.
- Provide policy recommendations at EU and local/regional levels.

Benefits of the project

- Develop a framework for multi-criteria selection and prioritization of policy options, within a participatory framework, to prevent groundwater pollution, combining technological and non-technological measures.
- Develop a software toolkit for the source apportionment method and release software toolkits for groundwater quality modelling.
- Promote passive sampling methods as a mean to control.
- Scale-up bio-based solutions to demonstration scale.
-

Contribution to the ZeroPollution4Water Cluster

- Recommendations at local level on policy options to improve water governance and prevent groundwater pollution processes that can be applicable to a wide number of sites.
- Recommendations at the EU level to improve the European policies dealing with groundwater, including proposals to update the list of pollutants subject to monitoring and control under the European regulations and directives (REACH, Groundwater Directive, Nitrate Directive, and others).

intoDBP

Innovative tools to control organic matter and disinfection by-products in drinking water

The intoDBP project focuses on disinfection by-products (DBPs) formed during water disinfection. It develops innovative tools for water quality management, emphasizing cost-effective sensors and analytical methods. intoDBP aims to:

- Develop a comprehensive approach from source to tap for an optimum drinking water (DW) surveillance strategy, based on state-of-the-art sensors combinations (UV-VIS, fluorescence, and toxicity) to measure and predict DBP formation and process anomalies in Drinking Water Treatment Plants (DWTPs).
- Foster Artificial Intelligence (AI) sensor deployment methodologies and algorithms in water delivery networks (WDN) to increase response reliability and forecast DBP transformations in urban networks.
- Develop a new transformative approach to simultaneously remove precursors and disinfect drinking water.
- Create a new open and ready-to-use workflow as a tool to enable forecasting the effects of climate extremes events on inputs of precursors of DBPs to drinking water sources.
- Increase the understanding of human exposure, taking into consideration gender dimension, to a wide range of DBPs in the EU population to generate and implement new models.
- Provide guidance to decision makers to formulate optimized and future-proofed climate change adaptation pathways.

- Compile and present new business opportunities.

Benefits of the project
• Provide knowledge and recommendations for the implementation of digital tools to achieve the new objectives of the drinking water and urban wastewater treatment directive. • Stress new business model opportunities. • Support local policymakers for the assessment of risks and implementation of tools related to DBPs and drinking water, particularly in Spain, Cyprus, and Ireland. More information included in the annex

Contribution to the ZeroPollution4Water Cluster

- Development of new technologies, such as MITO3X® technology to minimize reagent doses and reduce the formation of DBPs during pre-oxidation and final disinfection with chloramines, or sensor combining UV-VIS, fluorescence, and toxicity.
- Creations of new models to predict long-term changes in DOM in CS sites and short-term water quality threats arising from high DOM levels in source water in CS sites.
- Policy recommendations for the implementation of new European legislation.
- Exchange on business opportunities.

3. PART II: First Outcomes of the H20forALL & intoDBP Projects

H2OforAll and intoDBP projects have already released some public deliverables including first research outcomes on control-at-source perspectives and digital water gap in research and innovation perspective. This annex compiles these first outcomes.

1.1 Control at source: measures, methods, and tools

H2OforAll project has run a study to focus its research activities on a selection of 28 DBPs based on the most studied and regulated, most quantitatively present in water, the most toxic and the one which cover almost all the major families of DBPs[6]. The first activities of the project stressed that:

- Most DBPs are unregulated as of today.
- Known regulations on selected DBPs are from WHO, US-EPA, and EU. Other relevant bodies do not have regulations on DBPs as of today.
- For most DBPs, the estimated concentration range is regulated between 10 and 70 µg/L. However, this does not justify well the thresholds selected by international bodies for DBPs.
- Uncertainty on the specific natural occurring matter (NOM) types yielding distinct DBPs. Understanding better this relationship will help to understand the formation of DBPs and the overall risks.
- Better understand and quantify the health risks from the exposure to DBPs.
- Better regulate (at least the most important) DBPs and find consensus among policymakers globally.

The H20forAll project explored literature to understand crucial environmental parameters impacting DBP formation in drinking water and conducted a comprehensive investigation, identifying prevalent and toxic DBPs in chlorinated drinking water and assessing their impact on human health. A key challenge lies in pinpointing the specific type of NOM responsible for generating distinct DBP compounds.

In the same vein, the intoDBP project summarises different methodologies for the sampling and analysis of DBPs, including the DBPs selection. It aims to tailor the methodology to each case study's specificities. This methodology will be better explored to identify best practices at the end of the project's activities.

The intoDBP project also summarises the strategies for minimising DBP formation, with a particular attention to the DBPs regulated by the new Drinking Water Directive and emerging ones. The main conclusions for minimising DBPs in drinking water are [7] :

[6] H2OforAll, D3.1 Understanding and assessments of DBP's, *Innovative Integrated Tools and Technologies to Protect and Treat Drinking Water from Disinfection Byproducts (DBPs),* 2023.
[7] intoDBP, D4.1, *Strategies for DBP minimization*, 2023.

- Source water quality control: managing source water to lower the concentration and reactivity of natural organic matter (NOM) and bromide ion in the source water.
- Disinfection strategy selection, particularly by moving the disinfection downstream with lower dose and mixed disinfectants/oxidants as well as controlling the quality of the used reagents.
- Removal of DBPS precursors using the most efficient approach.
- Removal of already formed DBPs.
- Enhancement of the removal of inorganic precursors (eg. bromide)

1.2 A perspective on Digital Water

The exhaustive list (28) of DBP compounds, along with their associated parameters, presented in H20forAll serves as a valuable reference for researchers and industry practitioners. It acts as a cornerstone for future inquiries into the presence and impact of DBPs across diverse water sources, facilitating the creation of targeted treatment technologies and monitoring systems. Advancements in analytical techniques and sensor technologies have the potential to revolutionize DBP detection and monitoring in real time, facilitating proactive strategies for mitigation. Emphasis on emerging sensor technologies, novel analytical approaches, incorporation of artificial intelligence, and computer vision should drive future developments in this domain.

The new batch of targets for DBPs management in the Drinking Water Directive also encourages the mobilisation of digital tools, necessitating the identification of the most efficient way to place sensors and their development. Enhanced inter-connection between the ZeroPollution4Water and ICT4water clusters would be positive, especially considering the need for further research regarding modelling solutions as identified by the intoDBP project[8].

1.3 Research and Innovation Gaps

Most of the projects identified general trends that research and innovation policies will need to consider in the next programme to ensure access to drinking water in Europe:

- The increasing stress between water demand and supply and their higher risk of contamination, drought and flood, seawater intrusion and thermal pollution.
- The management of the contaminant of emerging concerns (CECs), including microplastics, antibiotic resistant bacteria and their social and environmental impact.
- The complexification of treatment strategies and their costs, including the challenge of old distribution networks.

Different recommendations have been identified by the project during the cluster meeting to respond to this health-related challenges:

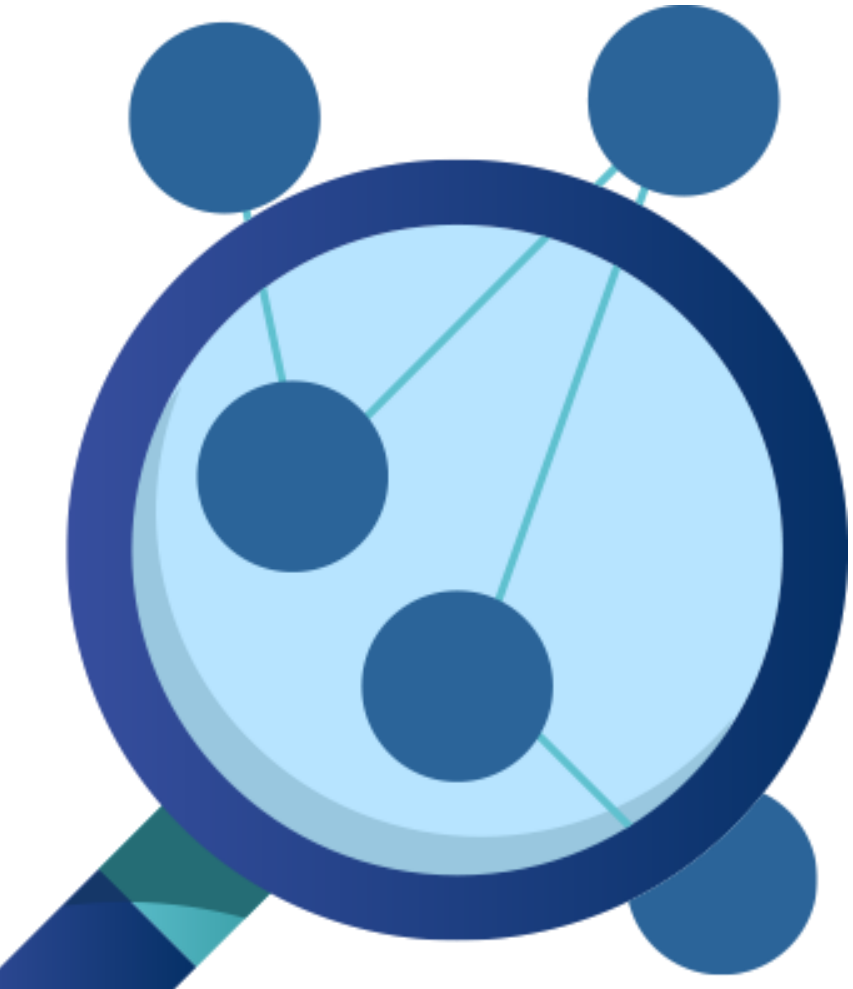
[8] intoDBP, D3.1, *Review of modelling solution for intoDBP*¸2023.

- Invest in R&I projects to develop cost-effective technologies for real-time data acquisition and removal of micropollutants, pathogens and DBPs.
- Gain better knowledge about the situation and impact of new Contaminants of Emerging Concern (e.g. through mapping) in terms of social aspects and potential policy measures to take.
- Incorporate in future R&I calls: living labs, strong training and awareness-raising programmes for society and all stakeholders particularly focused on CECs.
- Clarify and improve data requirements and management, particularly regarding the identification and monitoring of different antibiotic resistant genes (ARG's) and their impact on health.
- Invest in drinking water infrastructure, their design and operation to improve the resilience of our system.
- Improve the planification of wastewater reuse at basin level, including with aquifer recharge.
- Support biobased and nature-based mitigation solutions with a risk assessment.
- Minimise the pollution of micropollutants, including microplastics, pathogens and DBPs in drinking water networks.

intoDBP will create innovative tools and strategies to improve water quality management for safe human use and a healthy environment. It focuses on catchment protection and forecasting, transformative drinking water treatment, and real-time monitoring to combat the effects of climate and global change. In particular, intoDBP focuses on pollution and risks related to disinfection byproducts (DBPs). By developing and applying advanced, integrated, and cost-effective sensors and analytical methods, intoDBP will expand knowledge on water quality and DBP precursors to better understand its formation and human exposure in Europe. intoDBP monitoring results will feed into numerical forecasting tools to predict source water changes and formulate climate change adaptation pathways at catchment and treatment scale. intoDBP also develops transformative options for advanced and cost-effective upgrade of water treatment and disinfection.

In the intoDBP consortium researchers, small and large enterprises, communication experts and public services join forces to generate interdisciplinary solutions, that will generate a renewed perspective of drinking water surveillance, support decision-making and governance, and increase system resilience. intoDBP will implement and validate its cross-cutting products in four complementary case studies from three European countries where compliance with DBP regulation currently is an acknowledged challenge. The direct and visible positive impact of intoDBP in the case studies will foster rapid product adoption at a European and global scale, thus strengthening Europe's position and role in the global water market.

Reaching out beyond the water sector itself, intoDBP will directly engage society through surveys to analyze exposure to DBPs, collect data about catchment protection initiatives, create awareness and promote sustainable consumer behavior such as reducing bottled water consumption.



intoDBP

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