Research and Innovation Needs for Enhanced WFD Implementation

The European Network of Freshwater Research Organisations

Water for our Environment, Economy and Society:

Research and Innovation Needs for Enhanced WFD Implementation

(Version 2)

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Biebzra River, Poland

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This paper presents EurAqua's views regarding the knowledge gaps for which further research and innovation efforts are required in order to enhance the implementation of the Water Framework Directive and attain the objectives therein. EurAqua believes that addressing the Research Development and Innovation gaps here presented will not only strengthen our ability to reach the objectives of the WFD and the Sustainable Development Goal, but will also make Europe the international leader in water management.

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Abbreviations

HMWB: Heavily Modified Water Bodies

PoM: Programmes of Measures

SDG: Sustainable Development Goal

WFD: Water Framework Directive

1 Introduction

The European Network of Freshwater Research Organisations (EurAqua) is a forward looking network of 25 leading, mostly public, Research and Innovation (R&I) institutes contributing to the development and dissemination of European freshwater science and technology. EurAqua plays a major role in the development of the scientific basis of European water management as well as in policy decisions. EurAqua's members provide advice to national ministries and any other relevant regional authorities in charge of water management issues. At the European level, EurAqua's activities contribute to developing the knowledge base needed for the implementation of the Water Framework Directive (WFD) and related Programmes of Measures (PoM), in close collaboration with the responsible ministries and with the European Common Implementation Strategy (CIS) Working groups.

Despite the measures taken by Member States, many waterbodies still fail to reach the water protection objectives set by the WFD due to, amongst other factors, the strong pressure exerted by increasing population and rising consumption levels. Other than the demands imposed by the WFD, further effort is also required to reach the Sustainable Development Goals (SDGs) put forth in the Agenda2030, in particular SDG 6 'clean water and sanitation', SDG 13 'Climate Action' and SDG 15 'Life on land', but also SDGs heavily dependent on sufficient fresh water resources such as SDG 7 'clean and affordable energy'.

This paper presents EurAqua's views regarding the knowledge gaps for which further R&I efforts are required in order to enhance the implementation of the WFD and attain the objectives therein. EurAqua believes that addressing the R&I gaps here presented will not only strengthen our ability to reach the objectives of the WFD and the SDGs, but will also make Europe the international leader in water management.

This paper builds upon an internal consultation within EurAqua's member institutes, most of them house a good number of experts in the WFD. It is structured around 3 priority themes. R&I gaps within each theme are identified.

The three priority themes where R&I can significantly contribute:

1. Cross-sectoral and cross-disciplinary interactions in basin wide management, aiming to…
    - … accelerate the successful implementation of the WFD. Actions will also look at better aligning and integrating sectoral policies (e.g. agriculture, energy, transport, biodiversity) with the WFD as a way to enhance cross-sectoral responsibility in tackling WFD targets;
    - … support Europe's endeavours to implement the SDGs, together with other Global Agendas, such as the Sendai and Paris Agreements;
    - … facilitate sustainable use of water resources and ecosystem services while avoiding adverse effects on the good ecological and chemical status of rivers, lakes, groundwater, transitional waters and coastal waters.
2. Cost-efficient, reliable monitoring and status assessment, aiming to…
    - … improve decision-making on water resources management, climate resilience and water related risks;
    - … deploy enabling digital solutions for big data and innovative water technologies for the monitoring and assessment of hydro-morphological, chemical and ecological status of Europe's water resources, its uses and related ecosystem services.
3. Designing efficient and effective Programmes of Measures (PoM) aiming to…

- … reach good ecological and chemical status by addressing successfully multi-stressor conditions resulting from hydro-morphological changes and water pollution;
- … develop climate smart water management strategies and nature-based solutions to counteract climate change impacts.

When applicable this paper identifies cross-cutting issues that need to be further considered in the short and medium term. These cross cutting issues are:

1. **Emerging substances:** While this topic has been on the agenda for quite some time, the number of new compounds, especially in the light of for example pharmaceutical innovation, for which individual and combined effects remain largely unknown keeps rising.
2. **Specific water bodies:** A second cross-cutting issue here examined regards the specificities of certain water bodies for which not one-fit-all measures can be applied, for example: ephemeral streams (streams that flow only briefly during and following a period of rainfall) and small lakes, newly developed urban water bodies, transitional waters, and heavily modified water bodies us as reservoirs, in particular. These are briefly elaborated in chapter **Error! Reference source not found.** '**Error! Re ference source not found.**'.
3. **Climate change:** Last but not least, the impacts of climate change and its role in shaping the future of European water bodies is explicitly mentioned in different parts of the paper. Besides the evident effect on extreme flood and drought events, climate change will affect the ecology and hence the applicability of 'good ecological status' and 'good ecological potential'.

2 Cross-sectoral and cross-disciplinary basin wide management

2.1 Specific WFD challenge

The introduction of the WFD aimed to facilitate a shift from fragmented policies (energy, agriculture, etc.) to a holistic approach integrating all parts of the wider environmental system (Howarth, 2006)[1]. However, experience shows that this aim has not been achieved and that scientific efforts remain today confined to small scale studies. In addition, the requirement to develop RBMPs in a participatory process appears not to have delivered real community buy-in. In many transboundary river basins, RBMPs seemingly consist of compilation of sub-basin plans, lacking the overall view and considerations of geographical dependencies.

EurAqua thinks that there is a need for a more fully integrated approach, embracing the complete water-management system including policy, economy, social challenges, and the socio-hydrological and bio-geographical dimensions of the catchment system. Effective WFD implementation requires basin wide understanding of hydro-ecological systems, but moreover, about the interaction between a river basin / catchment system and the socio-economic system. This is defined by the dynamic interactions of a multiplicity of actors including, consumers, water use sectors and catchment stakeholder groups (e.g. agriculture, forestry, water abstraction, etc.) set in the context of the biological, biochemical and geomorphological character of a drainage basin. The coupling of these systems to climate change creates additional challenges for catchment scale control of freshwater systems, including the transport and propagation of pollutants from diffuse and point sources, flooding, soil erosion, sediment transport and effects on intermittent rivers.

2.2 Scope

New mechanisms of engagement at all scales, from local community to international and transboundary, need to be developed that can enhance and embed the principles of the WFD and its management units. Research and innovation activities should contribute to strengthening policy integration, coherency and water policy coordination whilst bringing a long-term perspective to policy implementation and decision making. A community-based approach needs to be developed considering water consumption and usage, floods and droughts and water quality that targets consumer and sectorial behavioural patterns within the water cycle, from the landscape level, to water treatment utilities, through to consumption and use. Smart holistic water policy systems that integrate values are needed to effect real change in society based on a new socially contextualised framework for WFD implementation. Such a community-based approach will only be realized if accompanied by novel governance approaches and societal contracts.

[1] Voulvoulis, N., Arpon, K.D. and Giakoumis, T. (2017). The EU Water Framework Directive: From great expectations to problems with implementation. Science of The Total Environment. **575**(Supplement C): 358-366.

2.3 Proposed approach

This challenge requires a (transnational) **catchment scale approach that links ecological and social systems in establishing a knowledge base for water management planning**. In particular, there is a need to address the links between behavioural systems, governance and management technologies which facilitates and promotes EU and international collaboration and partnerships on smart water-quality solutions and governance. This requires collaborative input from contributors in the arts, humanities and social sciences (AHSS) coupled with those in the science, technology, engineering and mathematics (STEM) communities. This approach recognises and capitalises on the development of new interdisciplinary models of management based on STEAM (Science Technology Engineering Arts and Mathematics) principles and acknowledges the holistic dimension of system management.

We further propose to integrate WFD with other policy agendas, such as the management of water under the UN-SDG targets, which takes a more cross-sectoral, inter-disciplinary approach for Europe and beyond. Research and development initiatives are needed for the formulation of a new socio-ecological management framework.

The approach needs to include: (a) problem articulation, vocalisation and identification; (b) societal needs and aspirations; (c) societal and legal barriers; (d) organisational constraints; (e) institutional contexts; (f) multilevel actions; (g) implementation and governance architectures; and (h) incentivising reinforcing mechanisms. The anticipated outcome of this approach is the development of a ***New Sustainable Water Management Model*** **integrating existing basin wide eco-hydromorphological databases and system understanding within the social context of policy implementation**. This will lead to the development of novel new smart protocols and tools that will target the gaps in WFD implementation that have been experienced to date.

Evidently, this approach requires basin wide understanding of hydro-ecological system – gaps in this understanding are mainly addressed in the section ‘pressures and responses’.

2.4 Expected impact

- Improved ability to reach the objectives of the Water Framework due to the development of a new River Basin Catchment Management paradigm;
- Public and sectorial buy-in, empowerment and joint responsibilities in implementing environmental policies in general and the WFD in particular;
- Narrowed gaps between the natural-science, social science including policies and governance.
- Enhanced ability to reaching the SDGs.
- Enhanced environmental services provided to citizens, and advance societal well-being;
- Increased competitiveness at MS & EU levels;

3 Enhance ability to assess WFD Status & reduce Monitoring Costs

3.1 Specific WFD challenge

Through the Common Implementation strategy (CIS) robust and comparable methods for ecological and to a lesser degree chemical status assessment have been developed across Member States. Now, however, there are great pressures from Member States governments to reduce the costs of monitoring whilst maintaining coverage and effectiveness. Many Member States are looking at innovative new methods to help deliver this improved cost-effectiveness.

To maintain public support for the WFD, progress needs to be communicated. To date, progress towards targets is limited due to the one-out-all-out principle. More progress has been achieved on underlying parameters. Additional agreed means to communicated progress are called for. This in particular holds for specific water types, such as ephemeral streams, or for specific pressures such as over-abstraction where the applicability of assessment schemes is limited. Finally, WFD assessment schemes require "climate-proofing": When and how do we need to adapt the WFD assessment targets due to climate change effects?

3.2 Scope

The research need in this field broadly encompasses three key areas.

1. Development and application of new innovative monitoring techniques.
2. Enhancing system and functional understanding in status assessment, particularly in relation to thresholds and likely impacts on ecosystem services.
3. Comparability of new approaches (under 1 & 2) to existing practice approaches and pathways to implement within the existing monitoring agreements, including means of communicating progress.

Concerning (1), significant progress has been made concerning innovation in monitoring, notably the use of remote sensing, metabarcoding and environmental DNA (eDNA), citizen observatories, effect-based analytical methods for main chemical drivers and mixtures, and automated sensor technologies for pollutants. Remote sensing comprises space-based technologies (e.g. ESA's Copernicus programme), unmanned aerial vehicles (e.g. drones), but also floating and submerged drones (e.g. hydroacoustics) and monitoring platforms. The big research need is in **demonstrating their comparability with existing inter-calibrated methods and their cost-effectiveness** (cost of delivering data in interpretable products and effectiveness in terms of pressure-response relationships and confidence in classification). Additionally the opportunities for combining and exploiting **big data** from these innovative methods should be further seized by Europe. There is a need for a **harmonized procedure for prioritizing pollutants and to develop related quality standards**. Pollutant prioritization can sometimes be achieved by employing exposure, effect and risk modelling as tools to fill gaps in chemical monitoring data and by developing methods for identifying toxic mixtures and trigger values.

Further research on **optimising monitoring network design for different WFD purposes**, such as status assessment, trend detection, diagnostics of cause of degradation, should be investigated and used to develop enhanced CIS guidance on this topic.

With respect to enhancing system and functional understanding (2) we need more insight in the complex non-linear nature of aquatic systems, considering the effects of **multiple interacting stressors** and the impacts of **climate change** on reference conditions and status class boundaries. We need to fill gaps in understanding system functioning and specifically the relationships between ecological status, ecosystem functioning and the sustainable delivery of ecosystem services. Demonstrating the value of improved status will strengthen public and political support for WFD PoMs, as well as to long-term observation measures of hydrosystems. Addressing non-compliant status elements is not necessarily the key to reaching good ecological status. Targeting other pressures and tipping points is expected to be more (cost) efficient, and it is also probable that the non-compliant status element will change. Currently our understanding of the system is insufficient to elicit the key driving forces determining the status / assessment result.

Emerging monitoring technologies open the door to new and high resolution data collection. Europe needs to seize the opportunity to combine these (big) data with improved, multiresolution modelling and analysis of the aquatic environment.

Given the current agreed and calibrated monitoring techniques, (3) how can new integrated methods be included in the WFD implementation process? Can we, and if so, how can we replace monitoring efforts by novel monitoring technologies seamlessly, that is without disruptions and monitoring induced step-changes and hence without decapitalization of what has been achieved? In other words, what are the pre-conditions that are needed to be met to allow Members States to be able to adopt more efficient monitoring compared to today? Within this development field, new agreed means to communicate progress towards WFD goals should be developed.

3.3 Proposed approach

The WFD challenges concerning the scale of monitoring required and associated costs, and a need to increase our system understanding to underpin PoMs can both benefit strongly by developing new monitoring technologies and making the most of big data and artificial intelligence. However it is essential to carefully develop the innovation and adoption steps, making sure new technologies are acceptable, can be integrated in current monitoring and assessment structures, and can be consistently used with historic data sets. The new monitoring technologies will also allow us to monitor microcosm and in- situ restoration pilots, advancing our system understanding to a level in which better targeted PoMs can be designed. The evidence base to pinpoint non-compliance to specific polluters and hence the ability to apply the polluter pays principle will increase. This will particularly hold true if we incorporate experimental design into routine WFD monitoring networks to better deliver system understanding both via traditional deterministic and statistical approaches and, leveraging the power of big data, computing power and artificial intelligence.

3.4 Expected impact

- Increased cost efficiency of monitoring by increasing the information amount obtained per euro spent.
- Enhanced coverage and improved confidence in WFD status assessments, and therefore an increased ability to develop more effective PoMs.
- Increased competitiveness of European monitoring and assessment companies.

4 Pressures & Response - Developing efficient Ecosystem Restoration Trajectories

4.1 Specific WFD challenge

In the previous sections we argued that improvements in whole basin management and in monitoring provide important building blocks to reach the objectives of the WFD. The key to reaching the goals however are the measures and, providing economic boundary conditions, it is key that the most cost efficient measures are selected on a basin level, considering all interconnectivity effects. While the cost of measures can be estimated well, the full effect of programmes of measures is often unclear in time and space. In other cases, system understanding is insufficient to set targets, let alone to devise measures to reach them, such as in ephemeral streams, whose abundance is often underestimated.

While our ability to assess effects of individual measures on a small system are reasonable, complex PoMs are more difficult to assess, in particular in the light of new pressures such as climate change and emerging substances.

Lack of dedicated evaluations after implementing measures further hampers our ability to provide scientifically underpinned insight in effectiveness.

In the light of this lack of knowledge, the adoption of the so-called "restoration trajectories" (water quality trends) following the application of measures seems to be a preferred option for water managers.

4.2 Scope - Research Need

In the light of the challenge presented above, further research is needed to develop climate sensitive, smart responsive, scientifically grounded PoMs and research to determine the temporal and spatial effects of measures. There is a need to **better understand how restoration trajectories are impacted** by individual and combined measures. Even if much research has been devoted to the understanding of linkages between the pressures executed by the chemical status (pollutants load) and the ecological status of a river system, a complete understanding of target levels is still missing.

One area that deserves further attention is the one on **cumulative impacts**. While cumulative impacts analyses have been operationally implemented by water managers, there is still a weak scientific foundation for some specific features of cumulative impacts. That is the case of for instance the interrelationship between land use and water quality of upland tributaries. We need to understand the cumulative contributions of different land uses as they change downstream if we are to develop meaningful water quality regulations. EurAqua proposes to direct more attention to the following aspects:

1. Characterisation of cumulative impacts through the use of innovative and cost-effective tools based upon modelling, GIS, trends analysis, indicators, etc.
2. Analyses of the causes, pathways and consequences. Attention should be paid to uncertainties and the costs involved in the assessment of cumulative impacts. Research must expand our knowledge on the connection between PoMs and their effect on ecological indicators (fish, plants, and fauna) as well as on the combined effect of multiple stressors on the ecological status of water bodies.
3. The promotion of a policy making shift in which cumulative impacts are taken into account in impact assessments and water management whilst bearing in mind the social and economic needs of stakeholders.

The upstream-dowstream connectivity is somehow overlooked in the WFD as a result of which the introduction of upstream measures is highly recommended. Research and innovation actions should help discern adequate upstream measures. The concept of "water bodies interconnection" and a whole-basin approach needs to be further considered.

4.3 Proposed Approach

This challenge requires a multilevel approach that combines different scales in pressures and geography, connecting multi-pressure laboratory experiments with field studies to basin wide modelling. We propose a programmatic, instead of a single-project based approach, building upon the successful projects that have already been executed, for example FP7 projects MARS and SOLUTIONS, making use of new monitoring technologies addressed in the previous section.

Key to this approach will be the connection between the experimental research scale and the full system understanding and modelling. EurAqua further proposes to look at all pressures (chemicals, nutrients, hydromorphology,..) on ecological indicators in conjunction, avoiding premature focus on single pressures. We propose specific attention to understanding tipping points and making them operational: Which PoMs will tip a water body into another ecological good status, and how will this propagate to the whole river basin?

In this approach specific attention should be paid to time-effects. When are we confident that the selected PoM will suffice, when do we require to take additional measures to tip the system into a better state?

The proposed approach will lead to better founded values for maximum acceptable pollution levels, e.g. Total Maximum Daily Loads. EurAqua proposes that the programmatic approach should also include governance/regulatory aspects such as advanced pollutant trading schemes or other means of implementing polluter pay principles.

4.4 Expected impact

- Improved, science-based and hence cost-effective development of PoMs, resulting from an increased understanding of status and multi-stressors;
- Operationalized decision framework for deciding on the necessity of complementary measures to be taken.
- New management practices to reach the WFD objectives.
- Advanced multiresolution modelling tools.
- European leadership in water management and restoration. Increased competitiveness of European monitoring and assessment companies.

5 Specific water bodies

In the previous section we have laid out three priority research areas that should significantly improve our ability to implement the WFD successfully. A few times the argument touched on specific cases or specific points of attentions. For completeness sake, these are briefly elaborated here. Research in the priority areas need to account for these specific cases.

5.1 Ephemeral streams

Intermittent or ephemeral streams are very common fluvial systems not only in the Mediterranean area. These rivers show a high rate of change in streamflow, high peak discharges, and low baseflow. A large part of their annual volume flows in a few days, delivering a great part of their sediment and nutrient loads downstream, often in reservoirs used for drinking water.

While they occur naturally, they are often 'men-made', and have profound effect on the wider (downstream) system. Typical Indicators of hydrological alteration fail to accommodate Ephemeral & Intermittent Streams.

Specific research and development needs comprise:

- Methods for the estimation and restoration of natural flow regimes;
- Understanding diversity and seasonal dynamics of biotic assemblages;
- Understanding of resilience of biota to increased desiccation duration;
- Refined classification and hydrological and ecological monitoring schemes;
- Development of specific PoMs.

5.2 Transitional waters bodies

Transitional water bodies exert a large variation of physical and micro- geographical characteristics (salinity, wetting/drying cycles). It is very challenging to set reference values and class boundaries for biological community indexes. Human activity in upstream waterbodies can heavily impact nutrient/sediment balance and species composition. The effect of sediment flows, both quality and quantity, is poorly understood and insufficiently accounted for.

Specific points of attention and research concern:

- Improved understanding of sediment dynamics and quality in the ecological status of transitional waters.
- Standardization of biomonitoring methods, for example based on bivalve molluscs.
- Develop monitoring and assessment methods that use molecular biomarkers

5.3 Urban Waters

Urban areas account for large use of water resources and exert significant impacts on water quality/quantity at the entire basin level. Urban areas are also subjected to hydrological extreme events whose impacts can be large due to the concentration of citizens and economic activities leading to increased transport of pollutants and nutrients and thus degrading water bodies downstream from urban areas. Urban sources are within the main responsible for the discharge of emerging pollutants into the environment.

Within the urban environment, man-made water bodies become more and more common to mitigate the effect of climate change (mitigating pluvial floods and urban heat island effects).

Specific points of attention and research concern:

- New treatment technologies for (emerging) substances in urban waste water;
- Cost- effectiveness of bioretention (of stormwater) measures on the aquatic system (including biodiversity) and on public health, compared to grey infrastructure. Identification of cost drivers, accounting for variability, and developing better tools for predicting costs for a better understanding of lifecycle costs for bioretention;
- Assessment of micro climatic effects of urban water management.

5.4 Heavily Modified Water Bodies

Despite the efforts of many Member States, there is still a significant number of Heavily Modified Water Bodies (HMWB) in Europe: more than 30 per cent of water bodies are classified as HMWB in the South of England, Poland and south-eastern European countries; this figure adds up to 50 per cent in The Netherlands, Belgium and Germany. HMWB are not properly tackled in Europe due to the costs associated with their restoration and the insufficient knowledge on best possible measures.

Specific points of attention and research concern:

- Developing novel cost-effective restoration measures. In those case where restoration is not feasible, develop new measures that significantly improve ecological potential;
- Improved decision framework for selecting dedicated PoMs for HMWBs.

6 Résumé

EurAqua has large experience in freshwater research and it provides advice to water management leading authorities across Europe. This experience has been mainly acquired through the participation of EurAqua in more than 80 projects concerning a wide variety of topics and ranging from ecotoxicology, ecosystem services and natural capital, water resources monitoring or regulatory frameworks, with particular reference to a good number of Framework Programme projects such as MARS – specifically launched to sustain the revision of the WFD –, SOLUTIONS or INSPIRE, to cite just a few.

In this position paper EurAqua has laid out three focus areas for research, development and innovation that will bring successful implementation of the WFD closer. We argue that we require a much stronger whole-basin approach including buy-in of other sectors, notably energy and agriculture, but also buy in of society / the public at large. We have argued that new developments could significantly enhance monitoring and assessment of our aquatic resources. Our understanding of the relation between measures and effects requires additional effort to achieve the goals of the WFD cost-effectively.

The proposed work will have profound impact on the WFD implementation. Taking a broader perspective, the work will have positive impacts on reaching goals of several other directives, notably, but not exclusively:

- Drinking Water Directive (Council Directive 98/83/EC);
- Habitats Directive (Directive 92/43/EEC);
- Birds Directive (Directive 2009/147/EC);
- Natura 2000 the co-ordinated network of protected areas;

Moreover, on a global level, carrying out the work will have beneficial effects on a number of Sustainable Development goals, especially Goal 6: target 6.2 on good water quality and target 6.6 on water-related ecosystems.

EurAqua offers to further exchange with the Commission on the content provided in this paper and to respond to any future demands in order to contribute to the sustainable management of our more precious resource: water.