White Paper

Hydropower & Biodiversity

Sediment Dynamics

ETIP HYDROPOWER

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Intended Purpose: The present White Paper is intended to provide European decision-makers with background information on key issues that are and will be discussed in pending and upcoming EU and national legislation processes relevant to hydropower development. These are, among others, the methodology for the establishment of free-flowing rivers and updates on ecological flows under the process of the Common Implementation Strategy (CIS) under the Water Framework Directive (WFD), as well as the implementation of the revised Renewable Energy Directive (RED III) and the Nature Restoration Regulation (NRR).

Hydropower plays a key role for the EU goal to decarbonize Europe's energy systems providing renewable electricity and increasingly important energy system services. This paper shows ways how hydropower can contribute to the achievement of European environmental goals and policies. It is part of a series of three papers on environmental topics related to hydropower; the other topics are Fish Mobility and E-Flows.

Executive Summary

Sediments are key components of riverine systems and therefore aquatic ecosystems. Moreover, effective sediment management is crucial for hydropower due to its significant impact on sediment connectivity. Run-of-river (RoR) hydropower plants alter sediment transport by modifying flow velocities and transport capacities, while reservoirs disrupt sediment connectivity within the river network - if not equipped with mitigation measures. Without proper tailor-made sediment management, the functionality of hydropower plants in the long-term may be compromised. Today it is possible to generate win-win solutions for the hydropower sector and the environment with existing technical standards, especially focusing on the sediment connectivity to fulfil the corresponding free-flowing criterium for longitudinal river connectivity. Important sediment management strategies include flushing, sluicing, venting and replenishment (1).

However, there is no common approach to implement necessary strategies in programs of measures (PoMs) nor dealing with sediment management within river basin management plans (RBMPs) up to now. The homogenization among so-called best practices in sediment management is necessary to make the regulations and permits according to environmental issues more flexible to the economic needs and to each infrastructure and environment peculiarity (each dam is a unique case study). Common methodological standards could serve as helpful tools. However, site-specific assessments are needed, and a toolbox of methods could support the process.

Sediment dynamics will increase in future due to both (i) climate induced changes (glacier melting, wash out of agriculture soil) and (ii) also due to the active management of hydropower facilities providing in principle important boundary conditions for a dynamic river system.

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Introduction Sediment and sediment dynamics in the hydropower aquatic environment

What is the importance of sediment dynamics in river systems?

Sediments are key components of riverine systems and therefore aquatic ecosystems (2). Sediment and sediment dynamics maintain the connectivity and the quality of the ecosystems connected to the river, and the local species (good ecological status or potential of aquatic fauna and flora) and to preserve the natural geomorphological balance of the river, required for the dynamic equilibrium of functional habitats (3). Moreover, sediment transport is crucial for the maintenance of the downstream environments, such as stabilization of downstream river section, coastline and deltas and the protection of the anthropic riverine and coastal infrastructures and economic activities (3). Sediments must be managed with a holistic approach, due to their relevance as a resource material, but they also come with needs and challenges, and affect the dam operation under the hazard perspective (e.g. ground water or extreme floods).

Why is sediment management important for hydropower?

Effective sediment management is crucial for hydropower due to its significant impact on sediment connectivity and related issues: environment, production, multipurpose reservoirs water uses, and safety issue. Run-of- -river power plants alter sediment transport by modifying flow velocities and transport capacities, while reservoirs without proper mitigation measure may disrupt sediment connectivity within the river network (1). As continuous deposition in impounded sections leads to losses in water storage volumes, proper sediment management ensures a stable and continuous power supply throughout the infrastructure’s lifespan. Strategies to prevent or mitigate reservoir sedimentation, or remove accumulated material, help maintain reservoir capacity and operational efficiency as well as safety conditions for dams and upstream and downstream riverine areas (2). Additionally, controlling sediment reduces the presence of solid particles in water passing through mechanical components like turbines, minimizing maintenance costs and the risk of equipment wear & tear or even failure (2). Finally, effective sediment management throughout the reservoir's lifecycle facilitates more feasible and cost-efficient end-of-life procedures, such as barrier removal.

How relevant is the catchment sediment management approach for different hydropower plant types?

Each hydropower plant and each reservoir have their own characteristics (shape, size, use, etc.), and may be in catchment areas with widely different geological and morphological features, therefore different strategies could be suitable for a particular type of plant. Without proper tailor-made sediment management, its functionality in the long term may be compromised. For example, some common elements can be glimpsed among different reservoirs highlighting similarities and proposing strategies for sediment management. However, it must be considered if dams are put into large river catchments, frequent overspill by ordinary flood events is transporting fine sediments to critical infrastructure like bottom outlets or turbine intakes. This can be part of a mitigation strategy but frequently causes serious technical challenges. Thus, the

selection of the hydropower plant type according to the natural boundary conditions (hydrology, sediment dynamics) is mandatory.

How sediment transport with relevance for hydropower can be measured?

There are several techniques using direct (bathymetries, bed load and suspended load samplers) and indirect measures (empirical estimation or numerical models; ADCP and turbidity probes for suspended sediments as well as geophones or hydrophones for bed load). Moreover, modern remote techniques relate watercolour to suspended sediment concentration. Each one can be suitable depending on the available economic resources or the on-site monitoring techniques affordability (drone or check sections along the inlet canals or rivers). More information is provided by the CIS guidance "Integrated sediment management Guidelines and good practices in the context of the Water Framework Directive".

What is today's common practice in Europe?

The Water Framework Directive guarantees a common legal basis, which also refers to sediments for the characterization of water body types, risk analysis, reference conditions, monitoring/assessment of status and so forth. However, there is no common approach to implement necessary strategies in programs of measures nor dealing sediment management within river basin management plans.

The common practice in central Europe is moving from a strict regulatory perspective that considers sediments as a "special waste" that should be treated with attention (increasing a lot the sediment removal cost), with respect to a more flexible and wise regulation that considers sediments as a part of the environmental process and "not negative" for the environment quality. However, the current regulation in various European countries such as Austria, Germany and Italy are quite articulated at several legislative levels (central state, regions, etc.) which offers a bit confusing panorama of sediment removal and re-utilization in the environment. If in future the sediment removal cost will drop thanks to more flexible regulations (sediment is not considered as "waste" anymore), some benefits are expected starting from the economically affordable restoration of the capacity of the reservoirs.

What is the problem with today's common practice?

There are no common standards, but good practices for single power plants, for cumulative and catchment-wide approaches to sediment management. In many cases, however, regulatory fragmentation and site-specific conditions hinder the homogenization and standardization of "best practices" or "efficient and effective frameworks" for addressing sedimentation issues and their ecological impacts, particularly on downstream rivers. Economic, environmental and societal constraints further complicate the feasibility of sediment removal and transport. Additionally, strategies are often developed with a narrow focus on individual infrastructure, or small groups of assets owned by a single company or stakeholder. This localized approach conflicts with the inherent connectivity of river systems, where interventions at one site can trigger cascading effects across the network, both spatially and temporally. Moreover, for fine sediments,

especially, there is only consideration of “waste” and not as “potential resource”. No or even too less attempts are made to integrate sediments of reservoirs or impoundments into circular economy strategies.

What are the future operational issues and research needs related to sediment management?

Since the “engineering problems” and “mitigation measures” are well documented with respect to sediment management, future operation issues and research need a better integration among stakeholders and governments to reach a trade-off between affordability and the applicability of the current regulation. The homogenization among so-called best practices in sediment management is necessary to make the regulations more flexible to the economic needs and to each infrastructure and environment peculiarity (each dam is a unique case study). Moreover, R&I efforts in innovative sediment management technologies should be incorporated like the venting of sediments in reservoirs, innovative underwater dredging with robots, resilience of hydromechanical equipment (gates, valves, runners) against sediment loading. Furthermore, work at the level of the local communities to increase awareness with respect to the sediment management issues is advisable, promoting a win-win situation among citizens, stakeholders and government to reach sustainable and modern sediment management. River systems have also to be targeted and addressed to be “fit” for more sediments. At the present stage river systems exhibit in many cases an unnatural lower supply and transport of both (i) coarse and (ii) fine sediments. Sediment dynamics will increase in future due to the active management of hydropower facilities providing important boundary conditions for a dynamic river system. Thus, the increase in resilience according to active sediment management must be discussed hand in hand what is possible and requested from an operational perspective including flood safety.

Conclusions

Sediment management is a big technical, economic and ecological challenge for the European hydropower industry. The loss of reservoir volumes - and thus generation and flexibility volumes - by 0.7 % per year in average on the European continent as well as ecological deficits downstream of power plants due to lacking sediment transport and –dynamics are challenges, which needs to be holistically addressed (multi-stakeholder approach). In parts, best practices for integrative sediment management are already put in place. However, no standardized methods are used for the assessment and implementation of relevant EU legislation harmonizing the sediment management approaches of various member states. Common methodological standards could serve as helpful tools. However, site-specific assessments are needed, and a toolbox of methods could support the process. Moreover, although many technical solutions are already available, the ecological standards about quantity and duration of sediment releases are missing, more basic research is needed on that. Climate change poses additional pressure on aspects of sustainable sediment management and resilience according to active sediment management and must be discussed hand in hand with what is possible and requested from an operational perspective, including flood safety.

Key Takeaways

- Sediment management for hydropower is part and interlinked with the "source-to-sea" approach of the Water Resilience Strategy.
- Sustainable sediment management must consider both, (i) economic and (ii) ecological needs and solutions by any stakeholders´ sediment management (including hydropower).
- Need to develop R&D on Suspended Particulate Matter concentrations acceptable for aquatic ecosystems - avoiding too hazardous or reversely too precautionary requirements.
- Sediment management for hydropower has to be technically optimised and aligned with natural processes to support the longitudinal connectivity in river systems.
- Sediment management for hydropower must be addressed as a "multi-stakeholder" approach including the polluter paying principle (e.g., hydropower in most cases not the sources for reservoir sedimentation).

References

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