THE RHONE SEDIMENT OBSERVATORY (OSR): A MULTI-PARTNERS PLATFORM FOR SCIENTIFIC AND APPLIED RESEARCH ON THE RHONE RIVER VALLEY (FRANCE).

L'Observatoire des Sédiments du Rhône (OSR) : une plateforme de recherche multidisciplinaire pour des recherches fondamentales et appliquées sur la vallée du Rhône (France).

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RÉSUMÉ

L'Observatoire des Sédiments du Rhône, créé en 2009, regroupe des équipes de recherche multidisciplinaires (hydrologie, hydraulique, géomorphologie, géochimie, géomatique, sédimentologie) en interactions fortes avec les gestionnaires du fleuve. Son objectif est de fournir des connaissances scientifiques pour promouvoir une gestion durable du lit, des berges et canaux, ainsi que des processus sédimentaires du fleuve, l'un des plus importants de la mer Méditerranée. L'Observatoire couvre l'ensemble du tronçon français du fleuve. Cette présentation propose une synthèse des avancées majeures après 16 années de recherche. Ces travaux ont permis de mieux expliquer l'évolution du chenal au cours du dernier siècle, de caractériser les habitats aquatiques et ripariens, et d'évaluer la sensibilité du chenal aux changements. Un réseau de stations permet de mesurer en continu les concentrations de matières en suspension (MES) et les contaminants inorganiques et organiques associés. Les flux de MES et de contaminants sont calculés automatiquement à partir d'une base de données et d'un outil de diffusion accessible aux scientifiques et gestionnaires. Des événements majeurs tels que les crues et des évacuations de sédiments de barrage sont suivis à l'échelle du fleuve. Plusieurs outils et protocoles ont été développés pour caractériser les processus sédimentaires, accompagner les acteurs du fleuve dans sa restauration, archiver les données et les échantillons, et diffuser ces informations aux gestionnaires.

ABSTRACT

The Rhône Sediment Observatory, created in 2009, involves an interdisciplinary research team (hydrology, hydraulics, geomorphology, geochemistry, geomatics, sedimentology) in strong interaction with river stakeholders. It aims to provide scientific knowledge for promoting a sustainable management of channel forms and sediment processes of this river, all along the main channel. A summary of the major findings after 16 years of research is proposed. They allowed to better characterize and explain the channel evolution of the last century, highlight aquatic and riparian habitat conditions, and assess channel sensitivity to changes. A network of monitoring stations is operating to continuously survey suspended particulate matter (SPM) concentrations, and to collect SPM samples for the analyses of their inorganic or organic contaminant contents. Fluxes of sediment and contaminants are calculated automatically from an open source database and an associated website accessible to scientific and stakeholders. Large events, including flash floods and sediment flushing, are also monitored at the river scale. Specific tools and protocols have been developed for monitoring sediment transfers, archiving data and sediment samples, and informing practitioners.

KEYWORDS

Contaminants, morphology, Rhône river, sediment, transfer

Contaminants, morphogénèse, Rhône, sédiment, transfert

1 INTRODUCTION

The Rhône Sediment Observatory (OSR), created in 2009, involves research teams from various disciplines (hydrology, hydraulics, geomorphology, geochemistry, ecotoxicology, geomatics, sedimentology) working in strong interactions with various river stakeholders. It aims to provide scientific knowledge for promoting a sustainable management of channel forms and sediment processes of this river, the most important in France and one of the most important for the Mediterranean Sea. The OSR covers the whole French section of 512 km long, starting from the French-Switzerland border down to the deltaic area in the northwestern Mediterranean sea. We propose here a summary of the major findings and developments after 16 years of research; we also focus on the evolution of the techniques and tools developed and applied for research and diffusion to stakeholders.

2 SEDIMENTARY CONTINUITY AND COARSE SEDIMENT FLUXES TO THE SEA

The analysis of bedload transport highlighted a general deficit in coarse sediment all along the Rhône River due to sediment trapping at the mouth of contributing tributaries (to prevent navigation problems), to in-channel mining and reduced transport capacity. Only the reaches upstream of Genissiat and downstream the Ain River confluence up to Lyon are characterized by active bedload transport. Results highlighted very significant sand fluxes, reaching the transport capacity of the river, for specific events (e.g., Isère sediment flushing, partial lowering of the dam water level – APAVER on the Upper Rhône, flood events). Methodological progress on continuous measurement of such sand fluxes will help to establish more reliable sediment mass balances. The progress in hydro-sedimentary modelling is also of great operational interest for testing sediment management scenarios, as it made possible to evaluate the transparency of the dams during bedload transport.

3 HISTORICAL CHANGES IN RIVER MORPHOLOGY AND IMPACTS ON AQUATIC HABITATS

The adjustment capacity of the river bed was reduced due to several factors: an incision triggered by the Girardon engineering works in the 19th century, a sediment starvation from the tributaries, a reduction in the transport capacity in the reservoirs and by-passed channels following hydroelectric developments during the 20th century. These morphological modifications of the bed had a strong ecological impact on the quality of aquatic and riparian habitats. In the absence of river dynamics, a homogenization of habitat conditions and associated plant communities is a risk. Therefore, the restoration of functional habitats for biodiversity requires actions aimed at promoting erosive capacities on the banks and the transit of coarse sediments (gravel and pebbles). The OSR scientists contributed to diagnose river status, identify restoration measures, and develop and test monitoring protocols using innovative techniques (RFID tracking) to evaluate river habitat improvement.

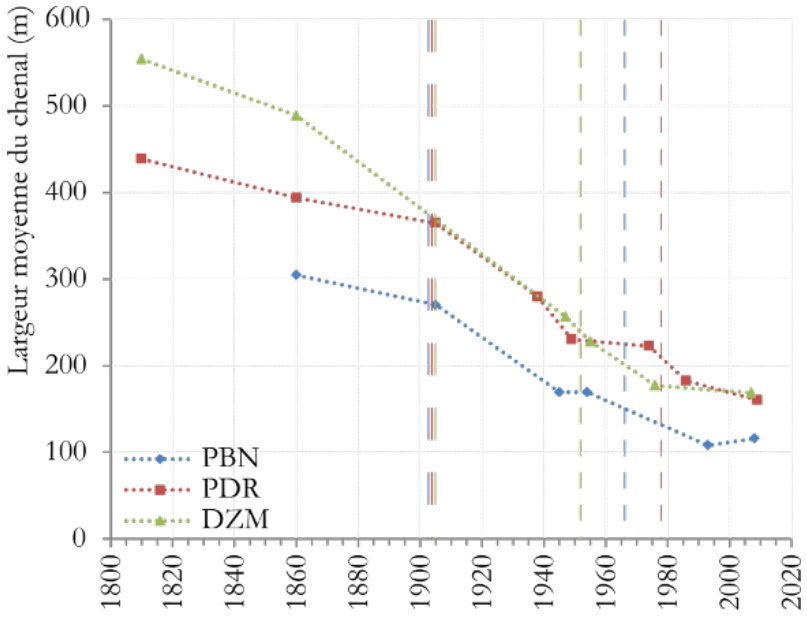

Figure 1 – Evolution of the width of dynamic Rhône river channel related to the different regulation periods between 1810 and 2009 (from Radakovitch and Piégay, 2022). PBN, PDR and DZM are three locations along the Rhone.

4 FEASIBILITY OF RESTORATION ACTIONS AND RIVER RESPONSES

Transdisciplinary discussions between scientists and river managers allowed to specify the different forms of restoration actions that can be implemented on the Rhône, depending on the intervention contexts and impacts. The identification of overbank sediments is a key step to select the reach for gravel augmentation associated to bank retreat (available volume, location along the continuum, quantities of fine sediment potentially contaminated, erosivity and shear stress). These reaches were characterized according to the quantity of material that can be introduced and transported, but also the potential risk due to the presence of past contamination (PCBs, trace metal elements). This allowed to strategically choose the engineering structures to be dismantled, while taking into account the erosive capacities of the channel near the targeted areas. Gravel augmentation is monitored using RFID techniques. This work allowed to better identify the relevant reaches for gravel augmentation and the necessary volumes, the sizes that can be mobilized, and the speed and transit time in the by-passed reaches.

5 CONSEQUENCES OF MORPHOLOGICAL DEVELOPMENTS OF THE CHANNEL ON THE FLOODING HAZARD

The OSR modeling work showed that during the 20th century, the flow conditions of the Rhône River have changed due to the narrowing and incision of the main channel, associated with engineering works for navigation and hydroelectricity, as well as mining. These changes induced variable hydraulic responses depending on the reaches and their morphological history. They did not significantly increase the water level but increased the water speed within the channel. The diversion of part of the flow by the hydroelectric developments of the 20th century contributed very significantly to reducing the frequency of flooding in by-passed reaches for current floods. The analysis of hydrological series has shown that a biennial flood before diversion has a 10-year return frequency, and that the propagation time of floods has been halved in two centuries due to hydroelectric developments.

6 SUSPENDED PARTICULATE MATTER AND ASSOCIATED CONTAMINANTS FLUXES AT THE SCALE OF THE RHONE RIVER BASIN

The network for monitoring the concentrations and fluxes of SPM and contaminants developed by the OSR (12 permanent stations; see Figure 2) has permitted to establish event-related, annual and interannual SPM mass balances across the entire river. Sedimentary export to the Mediterranean was on average 5.5 Mt per year for the period 2009-2021, with very high annual variability (between 1.8 Mt in 2010-2011 and 12.8 Mt in 2012-2013). Over this period, inputs from the four main tributaries account for 98% of this export to the sea. The seasonal and interannual variability of SPM fluxes are explained by the frequency and origin of floods. Two thirds of this export are transported during floods in November, January, May and June. On average, the Rhône system has a balanced sediment balance (total input by tributaries versus outflow to the sea), with annual variations linked to the temporary storage within the hydrographic network or release of SPM during floods and flushing of reservoirs. For contaminants (trace metal elements, polychlorobyphenyls - PCBs, aromatic polycyclic hydrocarbons - PAHs), the mass balances fluxes are often in deficit, suggesting that other sources of input must be taken into account as, for example, smaller mountain tributaries that could be highly contaminated by metals or direct discharges to the Rhône from urban areas (major sources of PAHs). For trace metal elements, as their concentrations are close to geochemical backgrounds, the contaminants fluxes vary mainly with those of SPM, and their seasonality follows the hydrological regime of the Rhône River and main tributaries floods.

7 SUSPENDED PARTICULATE MATTER AND CONTAMINANTS SOURCES AND DYNAMICS AT THE WATERSHED SCALE

Different geochemical methods and models have been developed and tested on various temporal and spatial scales to estimate the sources of SPM and associated contaminants. Results of these works are in good agreement and allowed to strengthen our knowledge on the relative contributions of the main tributaries to the Rhône River. In fact, the various tributaries show very contrasting levels of particulate contamination according to the contaminants studied, which we can explained by past or present activities on their watersheds. In the Rhône River, the concentrations of particulate contaminants have generally decreased or remained stable over the past 10 years (e.g., PCBs, trace metal elements, radionuclides); and they have decreased over the longer term as shown by their evolution within sediment cores collected in different sections of the Rhône. Nonetheless, particulate contaminants concentrations remain higher in the Rhône River at the outlet than upstream, and some

sources have yet to be characterized to explain these differences. Maintaining such a comprehensive monitoring network over a long period is essential to confirm or inform the trends observed, and to evaluate the policies implemented for the management of these contaminants.

Figure 2 – Monitoring network of SPM and sedimentary contaminants along the French Rhône River (from Radakovitch and Piégay, 2022).

8 STRUCTURING, SUSTAINING AND DISTRIBUTING RESEARCH RESULTS

All OSR productions (data, web applications, digital model, and publications) are publicly accessible through a specific website (https://observatoire-sediments-rhone.fr/). Data and metadata are available through open source and web tools (BDOH/OSR, MétaOSR, GéoOSR, Photo-DRIIHM). The 1D hydro-sedimentary model is a common and shared tool, as are the simulation results, which contribute to various actions of the OSR and its partners. With very short calculation times, this model allows the simulation of SPM transfer, sediment deposits and, in the near future, the evolution of the seabed across the Rhône River and over long periods.

LIST OF REFERENCE

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