Investigating the legacy sediments in the Péage-de-Roussillon bypass (Rhône River, France) by a combined geophysical and coring approach

Evaluer les sédiments impactés par les activités humaines au niveau du tronçon court-circuité de Péage-de-Roussillon (Rhône, France) à l'aide d'un couplage de méthodes géophysiques et carottages

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RÉSUMÉ

Le Rhône (France) est un fleuve fortement influencé par les activités humaines (urbanisation, pollution, infrastructures telles que les barrages et canaux artificiels, etc.), ce qui a conduit à la génération de larges volumes de « sédiments hérités ». Les efforts de renaturation du fleuve sont rendus difficiles par la présence de stocks de sédiments potentiellement contaminés sur ses marges alluviales (naturelles et artificielles). Cette étude a pour but de caractériser les conséquences de l'anthropisation sur la contamination et la dynamique sédimentaire du Rhône dans un tronçon court-circuité en aval de Lyon. Une méthodologie combinant des sondages géophysiques (ERT, GPR) et des carottes sédimentaires est appliquée. Elle permet l'identification de trois modes de sédimentation en fonction des caractéristiques morphologiques et/ou hydrologiques de la zone de dépôt, ainsi que l'évaluation de la contamination associée. La combinaison de méthodes géophysiques avec des carottages présente une vraie pertinence pour l'analyse des dynamiques sédimentaires en milieu fluvial.

ABSTRACT

The Rhône River (France) has been greatly impacted by anthropization (urbanization, contamination, infrastructures such as dams and artificial channels, etc.) which resulted in the creation of large volumes of legacy sediments. Efforts to restore the river to a more natural state is made difficult by potentially contaminated sediments stocked in natural and artificial margins. This study therefore focuses on the consequences of human activities on the sediment dynamics and contamination of the Rhône in a by-passed area downstream of Lyon. We use a methodology combining geophysical surveys (ERT, GPR) and sediment cores. This allows the identification of three distinct sediment patterns depending on morphological and/or hydrological characteristics, as well as the assessment of the sediment contamination. The association of geophysics with sediment coring is proved to be time and cost-efficient, and overall a promising tool to investigate sediment dynamics in a fluvial environment.

KEY WORDS

Contamination, fluvial sediments, geophysics, infrastructures, sediment cores

INTRODUCTION

The Rhône (France) is a highly anthropized river, impacted by infrastructures, contamination and a growing urbanization. It has been modified at the end of the 19th century for navigation purposes by channelization, and during the second part of the 20th century with the construction of by-passed sections for hydro-electric production. Those infrastructures have significantly altered the sediment dynamics in the Rhône, resulting in the generation of legacy sediments stocked in the natural (floodplains, backwater areas) and artificial (groyne fields, dams) river margins (Wohl, 2015). Since 2000, restoration projects have been implemented on the Rhône in an effort to improve the ecological and chemical state of the river and fulfill the requirements of the Water Framework Directive. However, the remobilization of potentially contaminated legacy sediments during those operations constitutes a health and ecological risk. It is therefore essential to quantify the volumes of sediments stored in the Rhône margins and understand their filling chronology and contamination level. In this study, we investigate the sedimentation patterns in the different types of margins of a 3 km-long reach of the Rhône, and assess in each case the sediment-associated contamination.

1 STUDY AREA, MATERIALS AND METHODS

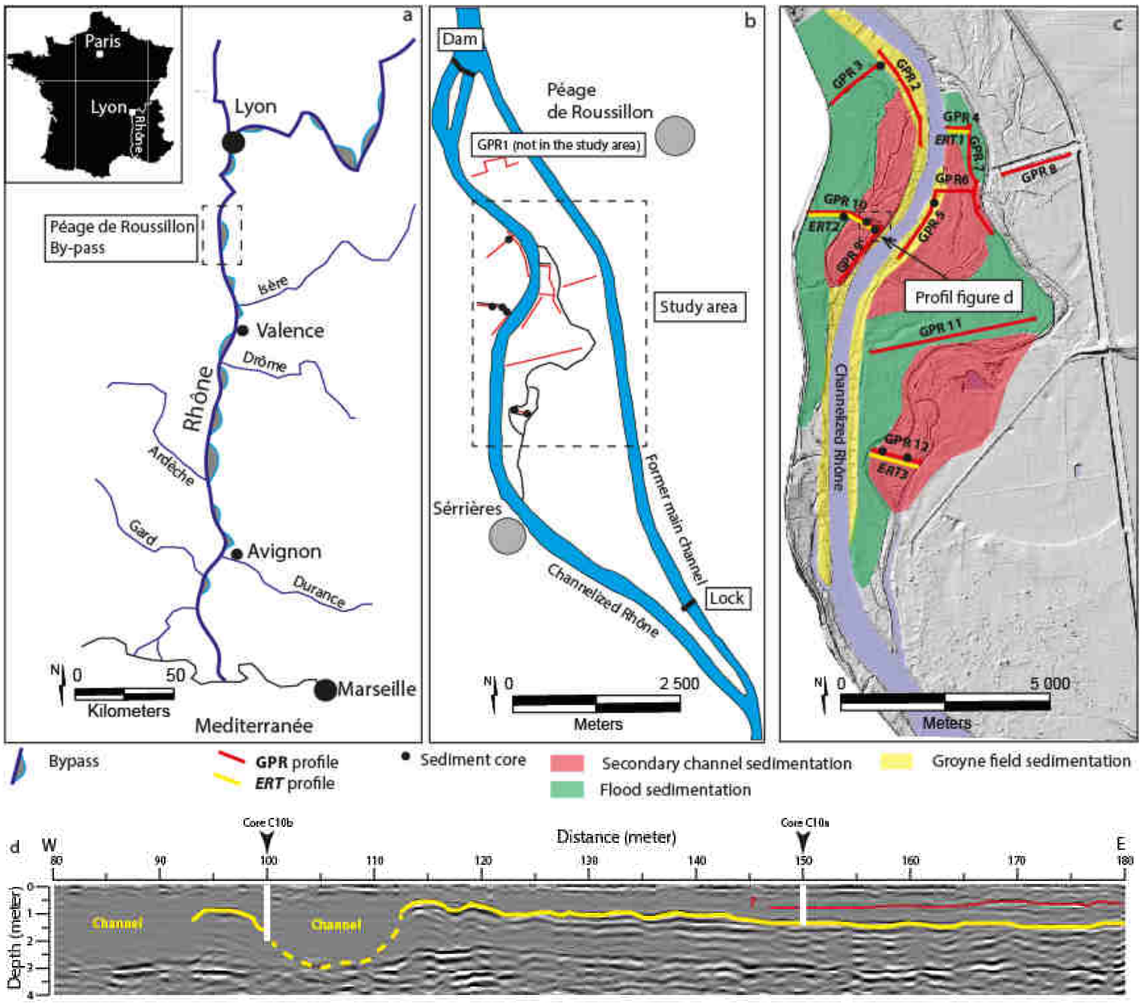

Figure 1: a/ Rhône bypass localization ; b/ Péage-de-Roussillon bypass ; c/ Lidar map, sedimentation mode and study area ; d/ Example of a GPR profile (part of GPR 10)

The study area is located in Péage-de-Roussillon, 50 km downstream of Lyon (figure 1.a). In this area, the Rhône is divided between the artificial channel and the former main channel with backwater areas and old infrastructures ("casiers Girardon" i.e. groynes linked to each other by a submerged dike) (figure 1.b and 1.c). A combination of 3 Electrical Resistivity Tomography (ERT) profiles (total length: 1 km), 12 Ground Penetrating Radar (GPR) profiles (total length: 6.5 km) and 7 sediment cores was used to investigate the subsurface structures and sediment characteristics of the area (Bábek et al. 2008). ERT was used to identify sites of interest in terms of sedimentation patterns that were then investigated in more details through GPR profiles. These surveys also allowed to position the sediment cores relevantly, where they would cross as many stratigraphic structures as possible and represent the modern sedimentary environment as a whole. The stratigraphy, magnetic susceptibility and grain-size distribution of the cores were determined with a sampling rate of 2-4 cm. A qualitative XRF Core-Scanner analysis with a 0.5 cm step was also performed, and metallic elements (Pb, Zn, Cu, Cd, Ni, Hg, Cr) were quantitatively assessed in all cores. Additionally, ^{137}Cs and ^{210}Pb dating and PCBs quantitative analysis were performed in 2 cores, with a step depending on the observed structures (mean step: 6 cm).

2 RESULTS AND DISCUSSION

2.1 Sedimentation patterns identified through GPR profiles

Three sedimentation patterns were identified after processing and interpretation of the GPR profiles (depth: 4 m) in association with LIDAR data: i) sedimentation in regularly-flooded natural margins, where fine sediments with continuous and sub-horizontal reflectors suggest that the deposition took place in a sheltered environment, ii) sedimentation in groyne fields, with layers of various thickness that illustrate a non-linear filling of the fields, and a continuous reflector at the top of the gravel layer, iii) sedimentation in the margins of the old Rhône with active and former secondary channels: the former channels form uneven reflectors that can be easily identified (see figure 1.d). Based on those results, sediment cores were sampled in each of the identified sedimentation environments.

2.2 Sediment cores analysis

Grain-size distribution analysis validated the conclusions drawn from the GPR profiles. Additionally, two main patterns were observed: i) constant median grain-size (D50 = 20-30 µm) associated with a continuous fine sedimentation and ii) peaks of D50 with a large range (up to 400 µm) associated with flood events. The metallic element contamination is moderate, well below the sediment quality guidelines (SQGs): average concentrations are 15.08 mg/kg for Cu, 23.38 mg/kg for Pb, 0.06 mg/kg for Zn, 19.32 mg/kg for Ni, 1.5 mg/kg for Cd and 0.2 mg/kg for Hg. No significant variation in contamination is observed between the different sedimentation environments. PCB pollution is low in the “secondary channel” and “flooded margins” sediments: the maximum $\sum PCBi_7$ concentration is 21.7 µg/kg. In the groyne fields, however, PCB contamination is significantly higher, with a median $\sum PCBi_7$ concentration of 85 µg/kg and a recorded maximum of 579 µg/kg. For comparison, median $\sum PCBi_7$ concentrations observed in fluvial cores in the Rhône upstream (île du Beurre) and downstream (Arras) of the Péage-de-Roussillon bypass were respectively 69.6 and 59.0 µg/kg, with maximum recorded concentrations of respectively 281.5 and 417.1 µg/kg (Mourier et al. 2014). Precise dating was impossible as no clear ^{137}Cs peak nor ^{210}Pb decline were detected. However, by combining the results of ^{137}Cs, grain-size distribution and contaminant analysis, we hypothesize that most sediments in the former secondary channels and floodplains were deposited between the beginning of the 20th century (the implementation of the groynes had a visible effect on grain-size distribution) and 1965 (before the maximum nuclear testing, which explains the lack of ^{137}Cs activity).

3 CONCLUSION

The applied methodology allowed to efficiently describe the sedimentation environment of the Péage-de-Roussillon bypass: i) 3 distinct sedimentation patterns were identified depending on the type of river margin it took place in; ii) Moderate but ubiquitous metallic contamination was observed, while PCBs were found in significantly larger concentrations in groyne fields than in other sedimentation environments, iii) chronology of sedimentation varies significantly between groynes field and floodplain compartments, the latter being largely disconnected since the early 20th century. The association of ERT, GPR and sediment coring is a promising methodology for characterization of sediment dynamics and contamination in a fluvial environment.

Acknowledgement: The authors thank the OSR 4 consortium for its financial support.

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