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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Introduction

The Rhône (France) is a highly anthropized river, impacted by infrastructures, contamination and a growing urbanization. It has been channelized at the end of the 19th century for navigation purposes, and by-passed sections were implemented during the second part of the 20th century for hydro-electric production. Those infrastructures have significantly modified the sediment dynamics in the Rhône, resulting in the generation of legacy sediments stored in the natural (floodplains, backwater areas) and artificial (groyne fields, dams) river margins (Wohl, 2015). These deposits disrupt the hydromorphological functioning of the river and are likely to contain anthropogenic pollutants. It is therefore essential to identify the effects of engineered structures on the sediments stored in the Rhône margins, understand their filling chronology and assess their contamination level.

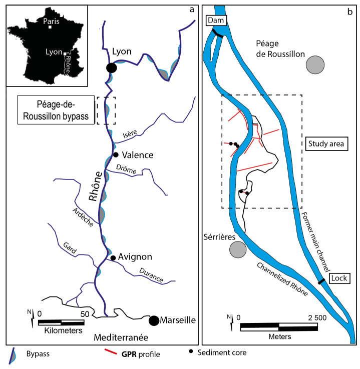


Figure 1: *a/ Rhône bypasses localization ; b/ Péage-de-Roussillon bypass*

Study area, material and methods

- The study area is located in Péage-de-Roussillon, 50 km downstream of Lyon (figure 1.a). There, the Rhône is divided between an artificial channel and the former main channel with backwater areas, old infrastructures ("casiers Girardon" i.e. groynes linked to each other by a submerged dike) and an upstream dam built in 1978 (figure 1.b).
- A combination of 11 Ground Penetrating Radar (GPR) profiles (total length: 6.5 km) and 5 sediment cores was used to investigate the subsurface structures and sediment characteristics (Bábek et al. 2008). The GPR surveys were used to position the sediment cores relevantly, where they would cross as many stratigraphic structures as possible.
- The stratigraphy and grain-size distribution of the cores were determined with a step of 2-4 cm. A qualitative XRF Core-Scanner analysis with a 0.5 cm step and a quantitative analysis of metallic elements (Pb, Zn, Cu, Cd, Ni, Hg) with a mean step of 6 cm were also performed in all cores. Additionally, PCBs and ^{137}Cs analysis were carried out in cores C10a and C10b (mean step: 6 cm), as well as radiocarbon dating in cores C10c, C12a and C12b.
- The statistical analysis of the results and the graphs presented below were done with the software R.

Results and discussion

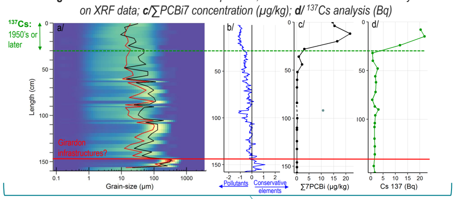


Figure 2: Core C10b - ***a/*** *Grain-size repartition;* ***b/*** *F1 coordinates from PCA analysis on XRF data;* ***c/*** *∑PCBi7 concentration (µg/kg);* ***d/*** *^{137}Cs analysis (Bq)*

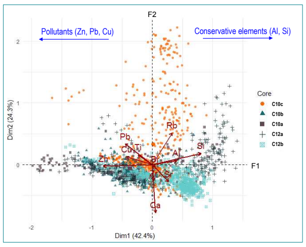


Figure 3: *Principal Component Analysis on XRF data – Biplot of variables and individuals, with color varying according to sediment core*

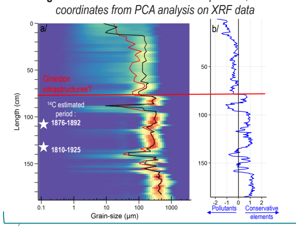


Figure 4: Core C12a - ***a/*** *Grain-size repartition,* ***b/*** *F1 coordinates from PCA analysis on XRF data*

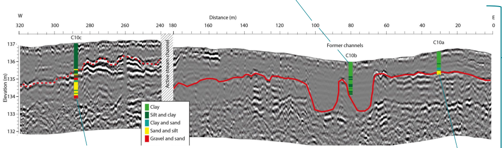


Figure 5: *Ground Penetrating Radar image with cores C10c, C10b and C10 a (from left to right)*

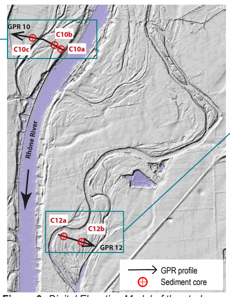


Figure 6: *Digital Elevation Model of the study area*

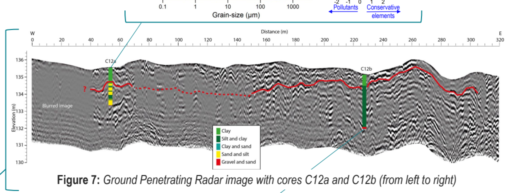
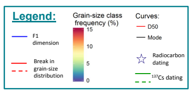


Figure 7: *Ground Penetrating Radar image with cores C12a and C12b (from left to right)*



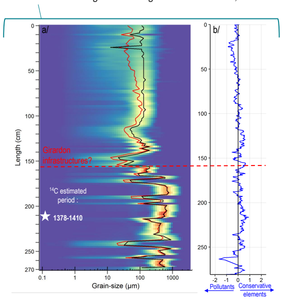


Figure 8: Core C10c - ***a/*** *Grain-size repartition;* ***b/*** *F1 coordinates from PCA analysis on XRF data*

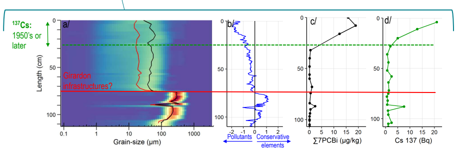


Figure 9: Core C10a - ***a/*** *Grain-size repartition;* ***b/*** *F1 coordinates from PCA analysis on XRF data;* ***c/*** *∑PCBi7 concentration (µg/kg);* ***d/*** *^{137}Cs analysis (Bq)*

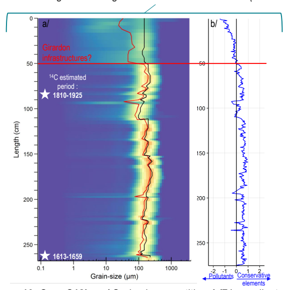


Figure 10: Core C12b - ***a/*** *Grain-size repartition;* ***b/*** *F1 coordinates from PCA analysis on XRF data*

In mg/kg	Cu	Pb	Zn	Ni	Cd	Hg
Average concentration	14.2	22.1	62.5	18.3	0.3	0.1
Max. concentration	45.2	53.7	161.8	32.6	1.4	1.1
PEC	**149**	**128**	**459**	**48.6**	**4.98**	**1.06**

Table 1: *Average and maximum concentrations in metallic elements (in all 5 sediment cores) compared to Probable Effect Concentration (MacDonald et al., 2000)*

- The GPR images reveal **2 main types of sedimentation pattern**:

1/ fine sediments with continuous and sub-horizontal reflectors that suggest that the deposition took place in a sheltered environment (e.g. figure 7); 2/ uneven reflectors that reveal active and former secondary channels (e.g. figure 5).

- A marked **break in the grain-size distribution** can be observed in the 5 sediment cores; it matches with a major reflector on the GPR profiles. Below the break, the sediments are rather well classified; above, the sediments are overall finer, the grain-size is more distributed and the mode and D50 diverge. We interpret this break as a consequence of the implementation of the "casiers Girardon" infrastructures in the 1880's. The radiocarbon dates (figures 4a, 8a and 10a) and ^{137}Cs variations (figures 2d, 9d) appear consistent with this assumption, but those results are still being discussed.
- A linear regressions between the XRF and quantitative analysis of metallic elements was computed and gave R^2 of 0.80, 0.61 and 0.37 for Zn, Pb and Cu respectively.
- The Principal Component Analysis carried out on the XRF data (figure 8) explains 66,7% of the variance with F1 and F2, which is satisfactory. **F1 seems to represent the level of contamination of the sediments**: we can then interpret the decrease in F1 coordinates close to the surface (figures 2b, 4b, 8b, 9b and 10b) as an increasing contamination in the most recent sediments.
- The area is **moderately polluted**: average concentrations in metallic elements are all significantly below the Probable Effect Concentration (table 1) and PCBs are found only in the top 30 cm of the cores (figure 2c and 3c) with maximum concentrations of around 20 µg/kg ($\sum PCBi_7$).

Conclusion

The implementation of the Girardon infrastructures in the Péage-de-Roussillon bypass resulted in the deposition of legacy sediments in the natural margins of the Rhône River. They are characterized as fine but poorly classified sediments situated above a significant change in grain-size distribution, and show a greater contamination compared to the deeper sediments. The association of GPR and sediment cores appears as a promising methodology for characterization of sediment dynamics and contamination in a fluvial environment.

References:

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