THE RHONE SEDIMENT OBSERVATORY: EVALUATION AND COMMUNICATION ON THE FLUXES OF PARTICULATE CONTAMINANTS AT THE BASIN SCALE

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One of the largest European rivers
First freshwater input to the western Mediterranean basin

560 km in France
(800 km in total)
Watershed: 98 000 km²

Mean discharge at the mouth:
1700 m³/s

Annual flood:
4000 m³/s

J.M. Olivier et al., 2009
Flash-flood events (few hours to days) occur regularly on the Alps and Massif Central Mountains (≈ 50-90% of the annual solid discharge in 10% of time)

Poor knowledge of the time and spatial scales and fluxes of sediment transported or stored within the river!
Regulated between 1850 and 1930 for navigation purposes... *(embankments, groynes, walls)*

… then dammed for producing electricity (1948-1986: 19 hydroelectric dams)

« Old Rhone » or by-passed reach

Embanked reach

Hydroelectric power plant
Why an observatory on sediments?


Stakes and questions related to the sediment transfer, morphology and contamination.

- What is the impact of the river geometry and existing infrastructures on the flooding risk or the ecological potential of the river?
- How has the geometry of the channel evolved over the last two centuries?
- What is the annual bedload transport?
- What is the impact of development and management activities such as dredging, channel maintenance or sediment flushing?
- What suspended sediment and contaminant fluxes are transferred to the Mediterranean Sea? Where do they come from and what are their temporal patterns?
- Can we predict the sediment transfer and deposition?
- How can we share data and information for stakeholders and public?
Alluvial margin restauration: feasibility, risks and opportunities

Flux monitoring

Knowledges to establish the diagnosis of the functional state of the river

Modelling, data banking and valorization

Observatoire des Sédiments du Rhone

2009 OSR 1

2019 OSR 5

Water agency and stakeholders

Regional councils
Some objectives related to fluxes of SPM and contaminants

◆ Choose the methodologies in order to collect Suspended Particulate Matter (SPM) in the river, its tributaries and in all conditions (especially during flood events).

◆ Define the collection systems, in order to get samples representative of the section, of the temporal variation and that can be analysed for both organic and inorganic contaminants (→ quality and quantity).

◆ Propose the best way to determine the SPM fluxes and those of associated contaminants, at the watershed scale.

◆ Define the best way to easily provide these values to stakeholders and public, with a high degree of confidence.
A network of permanent and temporary stations has been developed to measure SPM transfer and to collect samples for the analyses of contaminants and geochemical tracers:

13 stations were instrumented on the Rhone and its main tributaries to measure SPM and collect samples for the analyses of contaminants and geochemical tracers:

- 2 main permanent stations on the Rhone, upstream and before the outlet
- 8 permanent stations on the tributaries
- 3 temporary stations (one year)

Monitored from 2011 → 2016

Network in evolution

Liquid discharges obtained from CNR or « HydroFrance »
Sampling systems defined to obtain representative samples for geochemical analyses

- **Particles trap**
  - Sampling over 15-30 days

- **Fixed or portable centrifugation system**
  - « Instantaneous » sampling (2-4h)

- Calibrated Turbidity gauges are used for the estimation of SPM concentrations at fine temporal scale → precise evaluation

- Enough material can be distributed to all laboratories and stored for analyses
The SPM values and contaminants concentrations are available through a specific website (https://bdoh.irstea.fr) where fluxes can be calculated and data exported.
11 data producers, 22 stations, 43 parameters, 720 time series

Time series can be combined for visualization and calculation

Particulate Cd Concentrations in Arles

SPM concentrations
Contaminant concentrations are combined with SPM data for the calculation of fluxes. Anyone (including partners and public) may now use the same values.

Flux of particulate Cd (g/s)
Contaminants provided into BDOH:

- Co, Cr, Ni, Cu, Zn, Pb, Cd, Hg
- PCB
- $^{137}\text{Cs}$

Other contaminants or tracers measured:

- Numerous TME, rare earth elements, methylHg
- PAH
- PBDE
- Pesticides
- « Urban tracers »: pharmaceutics + pesticides
- Radionuclides associated to power plants releases (HTO, $^{14}\text{C}$)

This dataset helps to construct a good expertise on the transfer of SPM and contaminants.
SPM Data measured or reconstructed when missing through SPM-discharge relationship → precise estimation of present and past fluxes

Exemple 1: Providing validated SPM fluxes
Exemple 2: Defining the contribution from tributaries and the role of temporal storages

The role of dam flushing on SPM and contaminant transfers at the basin scale is still unknown by both stakeholders and public.

- Main contributors are evidenced.
- Dam flushing conducted each 4 years within the Rhone allow to « equilibrate » the SPM transfer.
Comparison of concentrations with sediment quality guidelines (*PNEC: predicted non effect concentration*), taking into account their temporal trends.

Calculation of the frequency of measures exceeding the threshold.

Simple map illustrating where the risk may occur (**support to Water Agency**).
Mass budgets allow to precise the origin of contaminants → inputs from tributaries vs output to the sea (Arles)
Exemple 5 : Estimation of the dose rate absorbed by reference organisms

Evaluation of the annual dose rate absorbed by Reference Organisms according to the ERICA methodology

CIPR reference values (Derived Consideration Reference Levels)

Predicted No-Effect Dose Rate for the ecosystem

Dose rate due to natural background (U, Rn, Ra...)

Dose rate due to artificial RN (gamma: $^{110m}$Ag, $^{241}$Am, $^{57}$Co, $^{58}$Co, $^{60}$Co, $^{134}$Cs, $^{137}$Cs, $^{54}$Mn, $^{125}$Sb)

Radionuclides dataset

Beaugelin-Sellier, Lepage, Gilbin
The objective is to model water and SPM transfer and fluxes over the whole river:

**545 km**

21 hydroelectric dams

6 major and 26 minor tributaries.

1D hydraulic model: MAGE

1D sediment model: ADIS-TS

Very fast calculation!

5mn running time for a 16 days simulation over 300 km (Lyon → sea)
An important goal is to reproduce the transfer and deposition during floods or flushing operations.

Simulation of the SPM content in Arles compared to real measures during a flood in 2008 due to Isère and Durance tributaries.

SPM Concentrations Arles [g/L]

Durance

Isère

Simulation of mass deposited and grain size distribution.

Storage of sediment in the dams.
A final objective will be to combine three hydrosedimentary models to get a source-to-sink simulation: RIVER \(\rightarrow\) ESTUARY \(\rightarrow\) CONTINENTAL MARGIN

1D-MAGE + ADIS-TS

2D DELFT
Deltares

3D – RHOMA + MARS
For IRSN, the objective is to combine his own models of hydrological and radionuclides transfer to get a source-to-sink simulation: RIVER → ESTUARY → CONTINENTAL MARGIN.

PhD starting in October 2018
A webmapping system provides an access to some geographical informations: maps and figures

Specific areas

Bathymetric profiles through time

Alluvial margin

Main channel
D50 values of the sediment

Pdf figures of some results
http://www.graie.org/osr/

Special issue
« Science of the Total Environment »
2018