A synthesis of long term contamination of French rivers revealed by sediment cores

La contamination des rivières françaises vue par les carottes sédimentaires : une vision de long terme

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RÉSUMÉ

Cette revue explore les données d'une série de carottes de sédiments datées, collectées dans les principaux bassins fluviaux français depuis 20 ans. Ces carottes, collectées dans des plaines inondables et des annexes fluviales, révèlent l'histoire récente de la contamination. Les métaux anthropiques classiques ont été mesurés toutes les carottes et des métaux moins couramment analysés sont également disponibles pour les archives les plus récemment collectées. Plusieurs familles de contaminants organiques (HAP, PCB et autres) ont également été mesurées dans certaines carottes. Les données sont traitées pour éliminer la plupart des biais qui pourraient apparaître lors de la transformation des concentrations sur les sédiments en concentrations représentatives des matières en suspension transportées. Cette étude se base également sur de nombreuses publications qui ont estimé les flux de suspension dans la plupart des grands bassins fluviaux français. Enfin, les flux historiques de contamination qui seront reconstruits en aval de chacun des grands bassins fluviaux sont comparés aux données démographiques et économiques pour produire des facteurs d'émission historiques consolidés à l'échelle nationale.

ABSTRACT

This review explores a series of dated sediment cores collected in major French river basins since 20 years. These cores, collected in floodplains and backwater areas, reveal the recent history of man-made contamination. Classical anthropogenic metals have been measured all cores and less commonly analyzed metals are also available in the most recent ones. Several families of organic contaminants (PAH, PCB and others) have also been measured in some of the cores. Data is treated to eliminate most bias that might appear when transforming concentrations on sediments into concentrations that are representative of transported suspended material. This study also relies on numerous publications that estimated suspended solids discharge in most large French river basins. Finally, the historical contamination fluxes that will be reconstructed downstream of each of the large river basins will be compared to demographic and economic data to produce consolidated historical emission factors at the national scale.

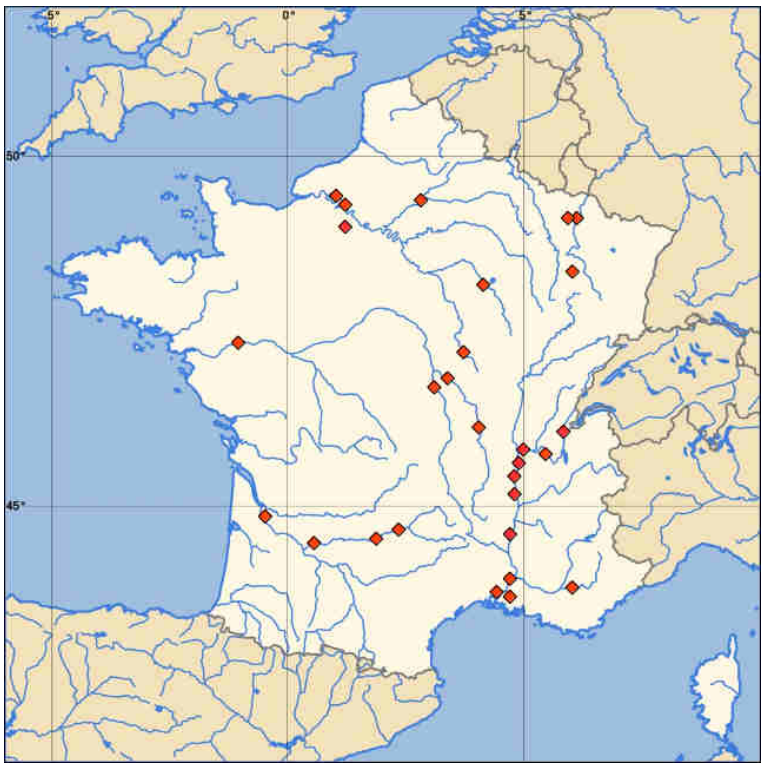
MOTS CLES

Sedimentary archives, anthropocene, contamination, river basin, France

1 AVAILABLE DATA

The history of contamination of the large French rivers (Rhone, Loire, Moselle, Seine, Gironde) has been studied during the two last decades. A series of sediment cores has been collected in various locations (floodplains or connected hydraulic annexes such as former harbors and sand/gravel pits or secondary channels), cores have been dated, and information regarding the level of contamination has been collected (trace metals -Pb, Cd, Cu, Zn, Hg, and others-, various groups of organic contaminants including older -PAH, PCB, OCP- and newer groups of components (phtalates, brominated compounds…). These cores cover periods ranging from 30 to 200 years. They have been dated using environmental radionuclides profiles (Chernobyl and/or bomb testing signals, ^{137}Cs) and recognizable hydrological events (major floods, man-made modifications of the alluvial channel….). Most of these results have already been published (see for example Grobois et al., 2012, Grousset et al., 1999, Lorgeoux et al., 2016, Mourier et al., 2014).

In many situations, a period of higher contamination is found during the period 1960-1970. It has been argued that strong evolution of industrial activities was the main factor explaining the decrease in concentration after this dark period. The awareness of society regarding environmental issues and the improved management and treatment of contaminant emissions could also have been a secondary factor. The most extreme contamination (Riou Mort, Orne, in the Lot and Moselle basins) was recorded in situations where the cores have been specifically collected downstream of ancient mining or industrial areas in the framework of a planned recovery of the sites.



Fugure 1: Position of the available cores in French river basins

Table 1: Selected trace metal concentrations in downstream cores of major river basins

River basin	Site	Core length (m)	Core depth (years)	maximum [present] concentation (ppm)		Date of maximum
				Cd	Pb	
Seine	Floodplain	1	1950-2003	44 [2]	460 [70]	1965
Garonne	Harbor	1.97	1910-1997	5.4[0.7]	140 [50]	1965
Loire	Floodplain	1.2	1900-2009	6 [1]	130 [45]	1965
Rhone	Floodplain	4	1960-2000	0.9 [0.2]	70 [30]	1960-1970

Table 2: Selected organic contaminants concentrations in downstream cores of major river basins

River basin	Site	Core length (m)	Core depth (years)	16 PAH (EPA list) (ppm) Maximum [present]	Date of max.	7 PCBi (ppm) Maximum [present]	Date of max.
Rhone	Annex	0,99	1987-2011			0,4 [0,1]	1992
Seine	Floodplain	1	1965-2010	90 [5]	1965	2,5 [0,25]	1970
upper Loire	Dam	1,3	1980-2010	13 [2]	< 1980	1,4	2008

2 COMPARATIVE ANALYSIS

A comparative analysis of the results obtained in cores collected in the different river basins might be useful to decipher the relationship between contaminant exportation by rivers in large basins and anthropogenic activities. Previous comparison showed that, putting aside the highly contaminated mining or industrial sites, the highest contamination levels (trace metals, PCB, PAH) have been recorded in the downstream part of the Seine river. This fact must be cautiously analyzed.

First, a normalization effort is required. Normalization to a reference element and/or a background level that characterize respectively the finer fraction and lithological inputs is common in trace metal geochemistry. A point is that the chosen references are not the same in all publications, but this small problem can easily be solved. For organic contaminants, the problem is more complex (normalize to organic carbon, black carbon for PAH, …), and a careful analysis of the data inside each core will be needed to choose the best procedure.

The second effort is to compare the contamination of transported particulate material and deposited material. Several data sets, unfortunately not always precisely where the core were collected, can be used for that purpose in the various rivers basins. In the case of floodplain deposition, sedimentation only occurs during floods where most of the solid discharge occurs.

The major key question is then to relate contaminant concentrations in one or few core depths into fluxes in the river at one period of time. Indeed, the lower concentrations observed in the Rhone river might be due to a much higher solid discharge diluting the waste emission. Here again, estimates of the solid discharge of the main French rivers have been published and discussed in the scientific literature. A simplified analysis based on the best expected Kd values will enable us to put aside components whose non particulate flux would be too large and poorly known, and estimated background levels will be removed.

These three steps being passed, it will be possible to reach the main objective of this study which is to relate past contaminant fluxes to human activities. Using historical distributed economic and demographic data from INSEE, we shall be able to elaborate emission factors, to describe their historical evolution, and to consolidate these estimations by comparing river basins.

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