# “*Longue Durée*” trajectories of river chemical quality indicators: the Seine case study (1900s-2010)

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## RÉSUMÉ

L’évolution des indicateurs de qualité des eaux, pour la Seine à l’aval de Paris, a été établie par les chroniques historiques, l’étude de la contamination de carottes de sédiment et par des modèles Pressions-Etat, sur la Longue Durée. Chaque problème de qualité des eaux présente des trajectoires différentes qui peuvent être reliées à des relations Pressions-Etat particulières. La dégradation maximale est observée en 1950-60 pour les métaux, soit 25 ans avant le début de la Réponse de la société, vers 1970 pour la pollution organique, vers 1995 pour l’eutrophisation et reste à venir pour les nitrates. Dans un tel hydrosystème avec des inter-actions Homme- fleuve ancienne, la Longue Durée est requise.

## ABSTRACT

The evolution of water quality indicators in the Lower Seine River has been established on the Longue Duree, through historical records, sedimentary archives of contamination and Pressures – State models . Each water quality issues shows peculiar trajectories, that can be linked to different Pressures- Responses relations. The peak degradation occurs at different periods: in 1950s, 25y before the start of societal response, for metals , in 1970 for the organic pollution, in the 1995s for eutrophication, and is still to come for nitrate. In such hydrosystem with ancient Human- river interactions, the Longue Durée analysis (ideally 100y) is required.

## KEY Words

Water quality, river, Longue Durée, organic pollution, nitrate, metals, eutrophication, Seine

# 1 INTRODUCTION

Rivers quality Trends of chemical water quality, the State trajectories, is generally assessed in EU rivers on short (<20y) to medium (20-40y) monitoring periods, depending on indicators. When addressing the complex relations between hydrosystems and their society, and their temporality, it is necessary to consider them over the *Longue Durée*, here defined as 100 years. The Seine basin in which the ratio Pressures/summer low flows, an indicator of sensitivity to points sources of pollution, is maximum, is a good candidate for such analysis. It also benefits from very early river monitoring and from a dedicated scientific programme, the Piren-Seine.

The indicators of water quality for the Lower Seine River, downstream of Paris megacity (today 10 million people, Mp) have been reconstructed using several approaches: (i) historical archives, initiated in the mid-1870s by the Montsouris Observatory and its following derived institutions (oxygen, nitrate, ammonium), (ii) by the reconstruction of indicators through Pressure-State models (nitrate, chlorophyll, bacterial counts), (iii) through sedimentary records of past contamination (heavy metals).We own up to the anachronism for evaluating the state of the aquatic environment, using the current scales of water quality throughout this assessment.

# 2 2 EVOLUTION OF THE STATE OF QUALITY OF THE LOWER SEINE RIVER

## 2.1 Organic pollution (1880-2010)

Organic pollution reached a high severity plateau that lasted from the 1870s to the mid 1990s. The selected indicator is the minimum dissolved oxygen level (mg/L) measured on a summer profile, downstream of Paris. This “Dark period” of extreme deterioration -using the present-day criteria- started as soon as the first Paris sewage collector was connected to the Seine, in the early 1870s and ended until the early 1990s, when the total capacity of Waste Water Treatment Plants (WWTP) – near 10Mp- finally matched the sewage collection. From 1870 to 1990 the sewage treatment was always lagging behind the increase of the population of Paris and its suburbs and their sewage collection.

## 2.2 Eutrophication (1950-2010)

Eutrophication developed in the 1960s then declined from the mid-1990s, due to a gradual phosphorus control, principally at WWTPs. It is measured here by the average summer chlorophyll, which has not been measured before 1985. Therefore its trajectory from 1950 to 1985 has been estimated from phosphorus- chlorophyll relationships. In 1976 early detection showed that eutrophication was already among the highest recorded in western EU countries.

## 2.3 Nitrate pollution (1880-2010)

Nitrate pollution issue developed gradually after WWII, accentuated in the 1970’s, and is still deteriorating in the Seine River basin. At Paris water intakes, nitrate-monitored since 1880- started to increase around 1950 with the use of chemical nitrogen fertilizers. In 1971 the nitrate monitoring was generalized throughout the basin and the quality scale used was the 1971 national one which considered a nitrate concentration < 25 mg/l as good to excellent, and <50mg/l as acceptable. Nitrate levels in the river were therefore mostly in the blue zone (<50mg/l), not in the red zone (>80 mg/L at that time) . The modeling of nitrate and other N species in the Seine (Billen et al., 2007) showed that nitrate fluxes to coastal waters were actually sustaining a high algal biomass. Safe levels of concentration for this criterium are indeed estimated to 2 mgN/l. This shows the complexity of water quality scales when based on the least demanding uses. Nitrate fertilizers are the prime origin of nitrate, so that when the main Paris Waste Water Treatment Plant completed its nitrate elimination, N fluxes did not show major change. We are therefore considering here a gradual quality scale targeted to nitrate inputs to coastal waters.

## 2.4 Heavy metals, Cd, Cu, Cr, Hg, Pb, Zn (1910-2010)

The metal contamination is only monitored since 1985 and background reference levels in river particles were gradually established from 1990 to 2003. The evolution of metal enrichment factors is based on cores sampled in the floodplain. The peak of contamination occurred around 1960 for most metals, i.e. some 15 to 20 years before the beginning of the use, in the late 1970, of restrictions. This results from several reasons: (i) Paris megacity has been gradually de-industrialized, (ii) there has been technical innovations as the drop of mercury anode in chemical industries and the change of coal-based electricity for nuclear energy, in the late 1960s, (iii) the recycling and the specific collection of metal containing waste waters in the plating industry,(iv ) the growing recycling of some important metal-containing products, as car batteries, (v) the metal-use regulations, as for mercury in the mid- 1970s, then cadmium in 1995. During the 1950 – 2000 period the demand for metal within the Seine basin increased with the economic development while the contamination decreased: the recycling of metal has been improved by nearly an order of magnitude, but metal levels (Cd, Hg, Pb,Zn) still remain largely above natural background .

Despite a severe state of metal contamination for nearly 100 years, this issue remained largely undeclared by river authorities. Its impacts on aquatic biota and Human health – through the consumption of fishes - remain unknown. The heritage of the long metal contamination has been raised only recently and due to more severe criteria for dredged sediments and crops, some old contaminated river sediments and soils can be now considered as “toxic wastes”.

# 3 CONCLUSIONS

Megacities located on relatively small rivers as Paris result in severe deterioration of contemporaneous chemical water quality indicators. This “Dark Age” period has lasted for more than one hundred years. In the Seine and Paris example the analysis of the societal Response – see Lestel et al., this conference- shows multiple causes and response lags, involving technical limitations, lack of scientific knowledge, lack of awareness, efficient lobbying against environmental measures, wrong water quality targets and, most of all, lack of institutions to raise funds and handle the issues.

Despite the major assets of the Seine River basin in terms of financial, human and institutional resources, the duration of the river restoration has been of nearly 50 years after the first Water Law regarding organic matter pollution and oxygenation, and could take again 50 years for reducing nitrate contamination. Considering other megacities of the world with higher development rates and, often, with less financial and human resources, it seems very difficult that they could produce sufficient responses unless major efforts and strong political will: without them these rivers are likely to be sacrified during a long period of time, as for the Seine River.

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