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Nutrient distribution and fluxes from three Mediterranean coastal rivers (NE Algeria) under large damming

Distribution et flux des sels nutritifs dans trois rivières côtières méditerranéennes (NE de l'Algérie) fortement soumises aux effets de barrage

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ABSTRACT

Nutrient distribution and fluxes into and from dams and into coastal waters from three rivers (NE Algeria) were assessed during a one-year period in three stations for each river: at the entrance and the exit of dam and at the outlet. The main characteristics of the rivers were the high levels of NH_4 and PO_4, even in dam entrances, contrarily to SiO_4 levels that are still low upstream the dams. From the inorganic nutrient incoming fluxes, the dams trapped annually 42 to 93%, depending on the nutrient, but released in great levels dissolved organic forms at their exits. At catchment scale, dissolved nitrogen loadings reach 338 kg/km^2/yr, in which the organic fraction forms up to 34%; while those of dissolved phosphorus reach 172 kg/km^2/yr, with a great organic fraction. The Si:N ratios decreased while N:P ratios increased at river outlets, indicating large inputs of N over P in the lower catchments.

RÉSUMÉ

La distribution et les flux de nutriments entrant et sortant des barrages et à l'embouchure de trois rivières côtières ont été évalués durant un cycle annuel à partir de trois stations aux embouchures et de deux stations représentant l'amont et l'aval de chacun des trois barrages. Les rivières se caractérisent principalement par les fortes teneurs en NH_4 et en PO_4, même avant d'aboutir aux barrages, à la différence de SiO_4, dont la teneur est déjà réduite en amont. À partir du flux minéral reçu à l'amont, les barrages retiennent annuellement 42 à 93 %, selon l'élément, mais libèrent à leurs avals des eaux fortement chargées en matières organiques dissoutes. À l'échelle du bassin versant, les flux spécifiques de l'azote dissous atteignent 338 kg/km^2/an, au sein desquels la fraction organique représente jusqu'à 34 %, cependant que celui du phosphore dissous n'excède pas 172 kg/km^2/an, avec une dominance de la fraction organique. Aux embouchures, le rapport Si:N diminue, cependant que le ratio N:P s'accroît, indiquant d'importants apports en N relativement au P dans le bas des bassins.

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1. Introduction

In recent decades, human activity has significantly changed the hydrology and chemistry of catchments by retaining rivers water in dams and by introducing large masses of fertilizers from agricultural, industrial and household wastes. Agricultural nutrient inputs and urban wastes are strong and increase with population growth. In the Mediterranean catchments, water river discharge is low and decreases with irrigation and climate change (Garcia-Ruiz et al., 2011; Ludwig et al., 2010). This context leads to an increase of river nitrogen and phosphorus concentrations (Abdelkader et al., 2012; Guasmi et al., 2010; Maane-Messai et al., 2010; Mouni et al., 2009). To fulfill the growing water needs, many dams have been built all around the Mediterranean Sea (see Lehner et al., 2011 for dam inventory). Dams may have a strong impact on the water and nutrient river discharge due to silicate and phosphorus retention within sediments and, but not always, due to nitrogen removing (Avilés and Niell, 2007; Dürr et al., 2009). Also, for specific irrigation dams, river nutrient discharge decreases with the increasing rate of water and nutrient uptake by crops (Wahby and Bishara, 1980). On another hand, nowadays in Algeria, the intercepted runoff in dams and weirs hold about 5.2 billion m^3, which form 42% of total runoff. Because of the growing irrigation needs and population intake, it is yet planned to store in the few coming years about 7.5 billion m^3, which represent 60% of the precipitation received in coastal catchments. Urban and agricultural nutrient inputs and water residence time within dams also lead to a change on the nutrients ratios, as the Redfield ratio (Ludwig et al., 2009). River nutrient discharge and nutrient ratios are known to play a special role in supporting the Mediterranean production (Béthoux et al., 2002) where the productive areas are limited to the adjacent coast (Bosc et al., 2004). However, there are few studies for the southern Mediterranean basins. In addition, data on river nutrient loading to the Mediterranean watersheds are also scarce and are missing in North-African countries and can bias the general picture (Ibáñez et al., 2008; Ludwig et al., 2009). Moreover, data on the distribution and fluxes of N, P and Si in coastal catchments of Algeria are inexistent, except the work of Khélifi-Touhami et al. (2006) that had only considered seasonal fluxes of inorganic N and PO_4 from the Mafragh estuary outlet. In addition, most studies about impacts of dams and river export of nutrients to the sea do not take into account organic compounds. However, some studies reveal that, even if the dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) are important components of riverine inputs and coastal catchments (Purvina et al., 2010; Wiegner et al., 2006), they are rarely considered within nutrient loadings pool. For example, Wiegner et al. (2006) reported that DON often dominates the total dissolved nitrogen (TDN), but yet it is not considered to affect coastal water quality because of its assumed refractory nature. The authors add that DON needs to be considered into coastal nitrogen loading budgets, because of its rapid bioavailability as well as its atmospheric deposition in watersheds that forms about 15–30% of the total bioavailable dissolved nitrogen (Whitall and Paerl, 2001). Again, even on a worldwide scale, DON and DOP have never been considered in dam budgeting studies and it is here the first attempt to consider these forms along the aquatic continuum of river systems.

Considering the severe lack of geochemical data for coastal river, this study aims to evaluate nutrient fluxes and dam effects on the biogeochemistry of N, P and Si in three representative coastal catchments of Algeria. Data analysis will focus on the effects of dams on nutrient retention and dissolved organic nutrient production and budgeting. The study on hand will consider, for the first time, the role of dams in producing DON and DOP and challenges to reveal that function.

2. Sampling sites

The three catchments have a total surface of 11 160 km^2 with a population of about 2 million people. They are mainly submitted to household and agricultural wastes (Fig. 1) and heavily managed by several dams that retain about half of the precipitation wealth. The largest dam is Beni-Haroun (960 million m^3 storage capacity) built on the Kebir-Rhumel River (KR; with a catchment of 8110 km^2). It is mainly used for water transfer to specific drinking water and irrigation reservoirs. But currently, only one reservoir (20 million m^3) is functional; it is allocated to drinking water. The diverted water is pumped irregularly, depending on water needs, at mid-distance from the two tributaries input areas within the upper dam. The water abstraction for irrigation is today limited to subsistent agricultural activities, even if it was planned to large-scale irrigation. The catchment of the Kebir western River (KW; 1900 km^2) is very weakly populated, with only 30 inhabitants per km^2 and it is managed by a dam that retains about 120 million m^3. This dam is used for irrigation and drinking water. The lower part is affected by marine intrusion and functions in the dry period as a core estuarine environment. This estuarine area does not exceed several kilometers. The Zardaza dam (50 million m^3) built on the Safsaf River (SF; with a catchment of 1250 km^2) is mainly used for drinking water. In the KR catchment, the great dam of Beni-Haroun was built in 2005 to intercept runoffs from the two main branches of Rhumel and Kebir. The Rhumel branch (Fig. 1) flow is more important than that of Kebir, but it is heavily submitted to direct untreated wastewater originating from Constantine city (about 1 Million people). The KR dam receives at its south side direct wastewater from the surrounding city of Mila and several other villages. Downstream the dam, the catchment is mainly forested and very weakly urbanized. By contrast to the eastern branch that is a temporary stream, the western branch of KW is a permanent stream receiving relative large urban wastes from used hydrothermal sources. The lower area of KW catchment is weakly populated, but relatively occupied by agricultural lands. The SF dam is alimented by the western stream that flows weakly but permanently. The upper part of the SF catchment is however largely forested and the lower part, relatively urbanized, is mainly occupied by agricultural lands. The catchments receive an annual precipitation