INPUTS OF PHOSPHORUS AND NITROGEN INTO THE MEDITERRANEAN SEA BY THE RHONE RIVER. VARIABILITY DURING THE LAST 20 YEARS

B. COSTE and F. [illegible]

Centre d'Océanologie de Marseille. Fac. des Sciences de Luminy. 13288 Marseille, France

Continental inputs of phosphorus and nitrogen into the Mediterranean Sea are connected to several features :
- 50% of the primary productivity in the dilution area (Gulf of Lions) are supported by phosphate and nitrate inputs by the Rhone river (COSTE, 1974).
- the continental inputs explain, for a part, the concentrations of phosphate and nitrate in the DEEP WATER OF THE MEDITERRANEAN SEA (MC GILL, 1968; BÉTHOUX AND COPIN-MONTÉGUT, 1986; COSTE *et al.*, 1988). Indeed, input (Atlantic water and river water) and output (Mediterranean Sea water) on the straits of Gibraltar are equilibrated. Modifications in the amounts of phosphorus and nitrogen by river discharges could contribute to modifications in the deep water concentrations. In this paper, we want to present Rhone river data obtained since 1968 and, more particularly, some recent data (1989 and 1990) to discuss their temporal variability.

Water input. The Rhône river is the main contributor to river water input into the western mediterranean basin. Its mean flow is 1700 $m^3.s^{-1}$; Ebro river is 200 $m^3.s^{-1}$, Arno river 103 $m^3.s^{-1}$, Tiber river 234 $m^3.s^{-1}$ (MARTIN and SALIOT, 1992). The Rhône river flow is very irregular: it varies from 500 to 13000 $m^3.s^{-1}$ and it presents a seasonal variability (maxima in autumn and winter and minima in summer)as well as an interannual variability (Table I).

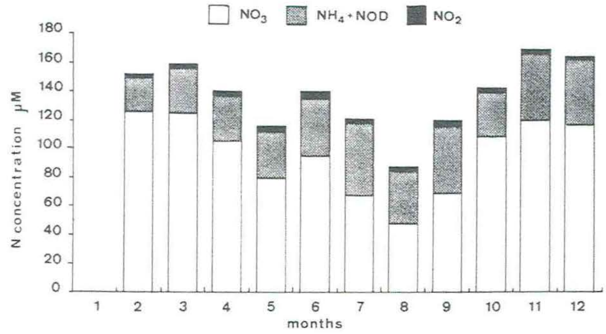
Table 1. main data concerning the Rhône river flow and nutrient concentrations during the 4 years studied.

Year		1968	1984	1989	1990
Mean annual flow (m3s-1)		1 829	1 678	1 061	1 301
Nutrient inputs	N	54 952	53 458	48 591	56 854
(tonnes.y-1)	P	4 064	6 454	4 712	5 077
Mean annual concentrations	N	68	72	104	98
(ml l-1)	P	2,2	3,8	4,4	3,9

Nutrient concentrations. Along the year, the nutrient concentrations vary within a ratio factor lower than 1 to 4. Nitrate are between 50 and 160 µM and phosphate between 2 to 9. These results are in good agreement with those reported by MEYBECK (1982). In 1984, we measured different forms of nitrogen compounds (fig. 1). Nitrite concentrations vary all along the year from 1 to 5 µM, ammonium plus dissolved organic nitrogen (DON) from 20 to 60 µM and nitrate from 50 to 160 µM. Some separated measurements for ammonium and DON show that DON is about 50 to 70% of the total. Then nitrate is the main source of nitrogen input but ammonium and DON have to be taken into account in estimating a mediterranean nitrogen budget.

Seasonal variability in the nutrient concentrations. Maxima concentrations in winter (November to March) and minima in summer (June to September) appear to be a general rule for nutrients (COSTE, 1974). For instance, nitrate concentrations show such a scheme in 1984 (fig. 1). Some exceptions, due to perturbations in the flow of the Rhone river, can be encountered. Such a seasonal cycle does not appear for the other forms of nitrogen. Nitrite does not show a significant seasonality. Ammonium+DON present only a slight seasonal signal with weak maxima in summer and autumn.

Figure 1: Variations in the concentrations of the different forms of nitrogen compounds along 1984.



Seasonal variability in the nutrient inputs. We can compute the nutrient inputs (tonnes.year^{-1}) from the values of the flow and those of the nutrient concentrations. The obtained results are characterized by a high seasonal signal because the higher concentrations values are concomitant to those of the flow. Thus the nutrient inputs are maxima at the beginning of the year and minima in summer with a ratio of 1 to 10.

Interannual variability. Table I presents the main features of flow and nutrient input for 4 years. It shows that: 1/ annual nitrate input is rather constant since 1968. Deviations from the mean value are less than 5%. Phosphate annual input is more variable and the recent data are 20% higher than the 1968 data. 2/ the mean concentrations of these nutrients are 50 to 70% higher in 1989 and 1990 than in 1968.

These results lead us to conclude that :
- a high seasonal signal characterizes the nutrient inputs all along the last 20 years. It is due to simultaneity of higher concentrations and higher flow values.
- the annual nitrate input has not varied significantly since 1968. Such a result has to be compared to variability of the mean annual values of the flow. The more recent data of the flow are 30% lower than the earlier. It seems that the low variability of the nitrate input could be explained by the flow variability.
- the variations of phosphate input could be explained by the flow variability but also by an increase in anthropogenic activity.

REFERENCES

BÉTHOUX J.P. & COPIN-MONTÉGUT G., 1986. Biological fixation of atmospheric nitrogen in the Mediterranean Sea. *Limnol. Oceanogr.*, 31: 1353-1358.
COSTE B., 1974. Rôle des apports nutritifs minéraux rhodaniens sur la production organique des eaux du Golfe du Lion. *Téthys*, 6: 727-740.
COSTE B., LE CORRE P. & MINAS H.J., 1988. Re-evaluation of the nutrient exchanges in the Strait of Gibraltar. *Deep-Sea Res.*, 35: 767-775.
MARTIN J.M. & SALIOT A., 1992. Bilan des apports fluviatiles et atmosphériques d'éléments et composés chimiques en Méditerranée occidentale. pp. 61-66, *in* : 3èmes Rencontres de l'Agence Régionale pour l'Environnement Provence-Alpes-Côte d'Azur, 24-27 Septembre 1991.
MCGILL D.A., 1969. A budget for dissolved nutrient salts in the Mediterranean Sea. *Cah. océanogr.*, 21: 543-554.
MEYBECK M., 1982. Carbon, nitrogen, and phosphorus transport by worlld rivers. *Amer. J. Sci.*, 282: 401-450.