ATMOSPHERIC INPUTS OF DISSOLVED INORGANIC PHOSPHORUS AND SILICIUM TO NW MEDITERRANEAN OLIGOTROPHIC COASTAL WATERS: THEORETICAL IMPACT ON PHYTOPLANKTON DYNAMICS

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Abstract

The atmospheric input of dissolved inorganic phosphorus (P) and silicium (Si) was monitored at the coastal sampling site of Cap Ferrat (Ligurian Sea). Their theoretical impact on phytoplankton dynamics was calculated on the basis of Redfield ratios. P-enriched atmospheric events may be responsible for significant episodic blooms, and might also episodically shift the chemical limitation of primary production in NW Mediterranean oligotrophic waters from P to Si.

Keywords: atmospheric input; oligotrophy; primary production

There is an increasing evidence that atmospheric inputs of nutrients have an impact on phytoplankton dynamics in oligotrophic conditions in the open sea (1-3), particularly in the Mediterranean Sea, owing to its reduced dimensions and because surrounding continental emission sources of nutrients are intense and continuously increasing. The theoretical input of wet inputs of dissolved inorganic phosphorus (DIP) and dissolved inorganic silicium (DISi) on primary production (PP) is examined here.

Rainwater was collected between 1986 and 2003 (102 samples) at the signal station of Cap Ferrat, SE coast of France (43° 41' N, 7° 19' 30" E). DIP was always analysed, DISi only from 2000. Phosphate and silicate were analysed by standard colourimetric methods. In both cases, the detection limit was 0.05 µmol liter^{-1}, and the blank values were always lower than the detection limit. Details on protocols can be found elsewhere (2, 4).

For each rain event, the wet input of a nutrient X (WI_X) is calculated as:

$$WI_X = C_X * H \quad (1)$$

where C_X is the nutrient concentration in rainwater and H is the rainfall amount. Maximum monthly atmospheric inputs of DIP and DISi averaged on the 1986-2003 dataset are given in Table 1.

Table 1: Maximum DIP and DISi inputs measured at Cap Ferrat between 1986 and 2003, with NP triggered by DIP inputs and compared with mean daily PP at the DYFAMED site.

Month	Maximum DIP input (µmol P m^{-2})	Maximum DISi input (µmol P m^{-2})	Atmospheric DIP-triggered NP (maximum observed inputs) (mg C m^{-2} d^{-1})	Mean daily PP (mg C m^{-2} d^{-1})
January				199
February	44.7	8.9	56.9	441
March	17.6	157.1	22.4	730
April	30.2	111.3	141.6	1187
May	70.1	18.3	89.2	518
June	16.9	86.3	21.5	493
July	310.5	182.4	395.0	518
August	263.25	56.6	334.9	234
September	200.1	144.3	254.6	276
October	529.1	1.1	673.0	219
November	24.3		30.9	155
December	114.0		145.0	236

Time-series data since 1991 at the DYFAMED station (Ligurian Sea, 43°25'N, 7°52'E) show that during the stratification period (July to mid-October), the nitrate/phosphate ratio in the photic layer is always > 20 and phosphate concentrations are very low in the 0-50 m layer (*5*), which confirms that P is the limiting factor in NW Mediterranean oligotrophic conditions. Hence, phosphate concentrations in surface waters greatly depends upon atmospheric events (1, 4, 6). In conditions of P-limitation, atmospheric inputs of DIP theoretically yield new productions (NP) calculated as follows:

$$NP = (DIP) * 106 * 12 \quad (2)$$

where 106 is the Redfield ratio carbon (C):P and 12 is the molar mass of carbon, in g mol^{-1}.

Table 1 shows the maximum monthly DIP-triggered NPs averaged over the 1986-2003 dataset (calculated from maximum DIP inputs) and compares them with the mean daily PP observed at the DYFAMED site (7).

Whatever the nitrate content in atmospheric inputs, the stock of dissolved N_2 can be considered as unlimited (assuming the existence of organisms capable of metabolizing atmospheric N in Mediterranean oligotrophic conditions) and, therefore, N does not limit phytoplankton growth. PP theoretically induced by significant rain events may be calculated on the basis of DIP wet inputs, insofar as no Si or iron limitation appears. It is clear that significant rain events in autumn can trigger a phytoplanktonic response able to strongly determine the mean daily PP. Rain events may thus significantly control phytoplankton dynamics at this period, much more than previously hypothesized (2).

Now can P-enriched rain events lead to episodic Si limitation? Dominant Mediterranean blooming diatoms that may gain by atmospheric Si inputs exhibit C:Si molar ratios of 4 (8). One can compute the PP induced by DISi atmospheric inputs using the relationship:

$$NP = (DISi) * 4 * 12 \quad (3)$$

The event of september 23th 2001 brought 200.1 µmol DIP m^{-2} and 144.3 µmol DISi m^{-2}, i.e. the Si-induced NP is much less significant than the P-induced one. This suggests that very high P inputs do not necessarily lead to proportional bloom of all phytoplanktonic populations. This event, although relatively rich in DISi, mostly benefit non-siliceous species, diatoms being rapidly limited by Si.

Although DISi data are still preliminary results, and under the hypothesis of N_2 fixation, the possible "secondary" limitation by Si might lead to the episodic preferential growth of non-siliceous phytoplanktonic species. Considering the increase of anthropogenic inputs of DIP (4), the frequency of blooms of non-siliceous species might increase too, which is in agreement with forecasting of Béthoux and coworkers (9). Future works should therefore focus on the study of specific phytoplanktonic biomasses related to atmospheric events, through pigment analysis.

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