La mer 29: 181-182, 1991
Société franco-japonaise d'océanographie, Tokyo

Nitrogen cycling in the upper layer of the open ocean as an indicator of organic fluxes

B. COSTE* and G. SLAWYK*

Introduction

For a part, interest in the studies on the biogenic element cycles, and more specifically studies on nitrogen, comes from the ability these elements give to reach the flux of organic matter from the euphotic zone.

Recent advances in the studies related to the nitrogen cycle

Over the last few years, many new results contributed to a better understanding of several processes related to the nitrogen cycle in the oceans. These results led to a new insight on the role this biogenic element plays in the studies on particle flux.

According to Dugdale and Goering, "new production" represents uptake of nitrate coming up from below the seasonal thermocline. "New production" is assumed as being equivalent to the export flux out of the euphotic zone. This assumption appears valid if measurements are averaged over an appropriate period. It has been demonstrated that there is a significant correlation between new production and flux of particulate material at the basis of the euphotic zone.

Attempts to estimate "new production" at a basin scale from remotely sensed temperature and fluorescence are under investigation and there is a way (which is at its beginning) to extract "new production" from remote sensing. This new approach could be very fruitful in flux studies whose first step is to know the spatial and temporal variability of the new production (or the flux of the particulate material) on a basin scale.

From the measurements of dissolved orgamic carbon (DOC) and dissolved organic nitrogen (DON) by SUZUKI *et al.* and SUGIMURA and SUZUKI using a high temperature combustion technique it appears that the concentrations of DOC would be 4 to 5 times higher in surface waters and 2 to 3 times higher in deep waters than previously measured. Though there still remains controversy about these new data on DOC and DON, we begin to realize that dissolved organic nutrients play a significant role in nutrient cycling.

Recent studies on nitrogen cycling done in French laboratories

The nitrogen cycle in the open ocean is being studied in France by laboratories of the University of Bretagne Occidentale and of the University of Marseilles. Similar works are being conducted in the ORSTOM agency, especially in Noumea.

We have essentially been active in two fields. First, we investigated nitrate fluxes in the upper layer of the oligotrophic ocean. This has been possible thanks to the development of an automatic colorimetric method for measuring nitrate concentrations lower than 100 nM with a detection limit of about 2 nM. This new method allows us to look at very low gradients of nitrate in the upper layer (1 nM/m) and to precisely monitor the disappearance of nitrate in field and laboratory experiments (uptake of nitrate by phytoplankton).

Nitrate above the thermocline may also originate from bacterial *in situ* nitrification. Therefore, the source of nitrate above the thermocline is a fundamental question. If the source is external, from deeper water as mentioned previously, then production associated with that nitrate is

*Centre d' océanologie de Marseille. Campus de Luminy. Case 901-F 13288, Marseille, Cedex 09

new production. If it is from nitrification taking place within the mixed layer, then the resulting production is regenerated production. Very recently, we developed a procedure using the isotope dilution approach to estimate nitrification in the north-east Atlantic. With this technique, we were able to detect and to quantify nitrification activity within the euphotic zone.

The second field in which we have been involved for only a short time is the role of DON in the nitrogen cycle of the oligotrophic ocean. We significantly improved a wet-oxidation method which allows us to better describe the distribution pattern of DON in the field and include these new data into those obtained from nutrient chemistry and hydrological survey.

As far as the role of DON in nitrogen cycling is concerned we still know very little about it. Only urea has been extensively studied. Using the ^{15}N tracer, it has been clearly shown that this organic compound is a preferential nitrogen source for marine phytoplankton. However, we don't have much information about how urea is recycled in the sea. Which are the organisms responsible for urea production ? What are the rates ?

These questions led us to the development of an isotope dilution approach using the ^{15}N tracer to examine the role of microheterotrophs in urea regeneration. Similar vertcal patterns of uptake and regeneration of urea seem to indicate that these microheterotrophs probably sustain totally the urea demand of phytoplankton.

Inspecting many data on inorganic nitrogen uptake as well as urea uptake showed that the amount of ^{15}N disappearing from the dissolved fraction is very often higher than the amount of ^{15}N which appears in the particulate fraction. One hypothesis, that has been put forward by many workers, is that phytoplankton excretes ^{15}N-labelled DON. This observation strongly calls for the need of considering the DON compartment when one will obtain correct estimates of nitrogen fluxes between substrates and biomass.

This hypothesis concords fairly well with the scenario of the functioning of the food web or microbial loop in the oligotrophic ocean. According to this scenario DON, mainly excreted by phytoplankton, is consumed by bacteria which themselves become the prey of nanoplankton. Backflow of inorganic nitrogen towards autotrophs is ensured by ammonium regeneration of microheterotrophs.

From these results emerges a new conceptual scheme of the functioning of the oligotrophic ocean: surface waters can contain trace quantities of nitrogen, especially ammonium, but also nitrate; small organisms are predominant and form a very complicated food web, called microbial loop, in which DON probably plays an important role; the spatial and temporal variability of physical, chemical and biological parameters is undoubtedly higher than previously thought.