
ABSTRACT

Different steps involved in the organic matter degradation (ectoenzymatic activities, aminopeptidase, phosphatase, bacterial biomass production, ^{14}C -glutamic acid assimilation and respiration) were studied throughout the whole water column, in the near-bottom water layer and in superficial sediments in the Ligurian Sea, the Gulf of Lion and the Ionian Sea. The relative homeothermy of the Mediterranean has permitted us to examine the effect of pressure on microbial activities independently of the temperature decrease. Data demonstrate that in deep waters, each step involved in the organic matter degradation is carried out by bacteria adapted to the ambient pressure. Indeed, during stratification period, metabolic rates measured on decompressed samples are underestimated by a factor equal to 3.6 ± 4.3 (mean \pm S.D.; $n=99$). Because the pressure effect is highly variable, a single factor cannot be used to correct rates measured with decompressed samples.

The use of pressure retaining samplers allowed us to demonstrate that the cells observed in the deep (>3500 m) anoxic brines ($S>300$) of the Ionian Sea were actually living organisms adapted to extreme conditions for life. Our data suggest that these cells are autochthonous populations able to participate to the geochemical cycles in these environments.

Sinking particulate matter is the major vehicle for exporting carbon and energy from the sea surface to the deep-sea. In spring 2000 in the Ligurian Sea, high fluxes of relatively fresh particles generated relatively small depth-integrated hydrolysis rates ($490 \text{ mg C m}^{-2} \text{ d}^{-1}$ aminopeptides hydrolyzed between 1000 and 2000 m), but a high glutamate growth yield ($\text{GY}_G = 65\%$). In contrast, in fall, a minimal flux of aged particles generated maximal depth-integrated hydrolysis rates ($1960 \text{ mg C m}^{-2} \text{ d}^{-1}$) and lower GY_G (12%). These results suggest that when the flow of particles is extremely low, bacteria must extract carbon and energy from the semi-refractory part of the dissolved organic bulk, such processes are costly in energy ($\text{GY}_G = 12\%$). In fall, the taxonomic structure of deep-sea bacterial populations were less diverse but different from surface populations. This discrepancy was probably due to the adaptation to high hydrostatic pressure conditions, and to the necessity to use more refractory dissolved organic matter.

Although decompression of deep-sea water samples leads to underestimation of microbial activities, decompression of near-bottom water samples provokes an overestimation relative to the actual rates measured *in situ* using a benthic lander. This apparent contradiction can be due to the difference in origin for deep-sea water and benthic water microbial populations. Metabolic rates measured on superficial sediment samples are higher by one order of magnitude relative to those measured in the whole water column. Potential fluxes of organic matter mineralization calculated through the surficial waters (until 200 m depth), intermediate and deep-sea waters (200-2000 m) and benthic layer (near-bottom waters and superficial sediments) suggest that in the deep compartments of the Ocean, the potential metabolic processes are far from negligible.

Since attached bacteria plays an important role in the mineralization of particles and in the recycling of biogenic elements (silicate and carbonate), we did an experiment to simulate the fall of particles through the whole water column. This experiment demonstrates that bacteria attached to the sinking phytoplankton aggregates are influenced by increasing pressure. The gear we developed for this experiment will allow to precise calculations for sinking particle mineralization and dissolution throughout the whole water column.

The experimental approaches we used to study deep-sea waters, sinking particles and benthic waters, respecting the main conditions of these deep-sea environments, permit to study quantitative and qualitative evolution of the chemical composition of the organic matter, microbial diversity, from the sea surface to to the bottom. This strategy will lead towards a better estimation of carbon and energy fluxes that insure pelagos-benthos coupling, one of the main keys of the Global Ocean functioning.