ROLE OF ULTRAVIOLET RADIATION IN THE MEDITERRANEAN SEA: INTERACTION BETWEEN MIXING PROCESSES, PHOTOCHEMISTRY AND MICROBIAL ACTIVITY

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Abstract

Ultraviolet (UV, 280-400 nm) radiation penetrates deeper into the water column than previously assumed and acts on dissolved organic matter (DOM) as well as on planktonic organisms. Evidence is presented that originally labile DOM is becoming more refractory upon UV exposure while refractoy DOM becomes more labile. The development of a pronounced diurnal thermocline leads to a prolonged exposure of DOM and microorganisms entrappped in the uppermost water layer to UV radiation. Only, when the diurnal thermocline breaks up in the late afternoon, the upper water column is mixed again and the photolytically cleaved DOM is made available to bacterioplankton.

Key-words: Plankton, bacteria, pelagic, surface waters, global change

Introduction

More than 2 decades ago, our view on the carbon and energy flow through marine ecosystems was challenged by the finding that bacterioplankton are much more abundant than perviously thought [1] and that they are responsible for the major part of the respiratory activity in the water column [2]. The notion that bacterioplankton growth is roughly in the same order of magnitude as phytoplankton primary production [3, 4] and that they are efficently grazed by protists [5, 6] placed them into the center of a microbial food web [7, 8]. In this "microbial loop" [7] carbon and energy is efficiently recycled and competes with the metazoan food web for the available organic material [9, 10]. Currently, molecular approaches are applied to decipher the bacterioplankton species distribution over time and space in order to better understand the interactions within the bacterioplankton communities [11-14]. To date there is no doubt about the significance of bacterioplankton within the planktonic communities. In oligotrophic environments, bacterioplankton dominate over phytoplankton biomass even in the euphotic zone and represent the largest living surface in the sea [15, 16].

The discovery of a major ozone hole over Antarctica and its spreading to mid-latitudes during the austral spring [17, 18] stimulated research on the role of the accompanied increase in ultraviolet-B (UVB, 280-320 nm wavelength) radiation reaching the Earth's surface [19]. This research originally focused on Antarctic systems since major fishery resources are located there; the initial scietific question centered around the extent the productivity of these Antarctic systems might be influenced by the increased UVB radiation [19-22]. UVB increases, however, not only in the near-polar region of the southern hemisphere but is on the increase also in mid-latitudes of the northern hemisphere [23]. Thus, the increase in UVB radiation might also have an effect on temperate marine ecosystems. At northern temperate latitudes, ozone levels in the early 1990's were about 10-15% lower than that estimated in the late 1970's, when compared on an annual basis [24]. Translated into DNA damaging weighted biological radiation, these ozone reductions amount to a nearly 10.5% increase in damaging dose, or an average of about 0.75% per year for the last 14 years [25]. The change in stratospheric ozone, however, has little effect on the flux of incoming UVA (320-400 nm) radiation or photosynthetic active radiation (PAR, 400-700 nm). Thus, changes in stratospheric ozone alters the spectral balance between UVB: UVA:PAR. As outlined in detail below, these changes in the spectral balance have a severe impact on the recovery of organisms from UV stress.

The Mediterranean Sea and particularly the Adriatic Sea is heavily exploited by fishery and, moreover, an economically important region where millions of tourists spent their vacation every summer. Thus, possible alterations in the food web and the carbon flow through theses systems due to altered UVB radiation regimes might have a profound influence on the sustainable use of the Mediterranean Sea in general and the Adriatic in particular.

In this contribution we will first pinpoint the major role of UV radiation on the dissolved organic matter (DOM) pool which is one of the largest organic carbon reservoirs of the biosphere [26]. Then we discuss the impact of UV radiation on the living biota, in particular, the bacterioplankton as the principal consumers of the DOM pool and, finally provide a synthesis of the possible interactions between the DOM and bacterioplankton as influenced by UV radiation. Possible scenarios are then drawn on the impact of increasing UVB radiation on the carbon flux through the pelagic food web in the Mediterranean and the Adriatic Sea.

The radiation regime and its impact to the stability of the water column.

As shown in Fig. 1, even short wavelength UV radiation (305 and 320 nm) penetrates to considerable depth in the coastal Northern Adriatic Sea. In open oligotrophic environments such as the tropical Atlantic, the 10 % radiation level of the 320 nm wavelength is at about 25 m, while the 10 % radiation level of the 340 nm and 380 nm wavelengths is at 35 m and 60 m depth, respectively (Obernosterer, unpubl. data). This radiation, particularly in the UV range, has an direct impact on the DOM and the biota in these layers as outlined in greater detail below. However, also longer wavelength radiation (> 700 nm) influences the upper water column by introducing heat over a diurnal cycle (Fig. 2). During the night, surface cooling and convection result in a nearly well-mixed boundary layer with a small unstable surface layer [27]. Solar heating leads to rapid shoaling of the boundary layer and the formation of a diurnal thermocline (Fig. 2). Following sunset, surface cooling erodes the stratification and deepens the boundary layer again (Fig. 2). Diffusivities are large during the night-time with peak values exceeding 300 $cm^2\ s^{-1}$ [27]. Daytime diffusivities are more than one order of magnitude lower due to the shallow boundary layer and reduction in the turbulent velocity scale under stable forcing [27]. Thus, the long wavelength spectrum (> 700 nm) of the solar radiation establishes a diurnal thermocline in the upper water layer creating a surface layer where DOM and non-motile plantonic microorganisms are trapped over almost the entire period of sunshine. In the open oligotrophic ocean, this layer of reduced turbulent mixing extends from the air-surface interface to about 15-20 m depth (Obernosterer, unpubl. data). The shorter wavelength spectrum of the solar radiation (300 to 400 nm) acts on the DOM and the biota entrapped in this layer.

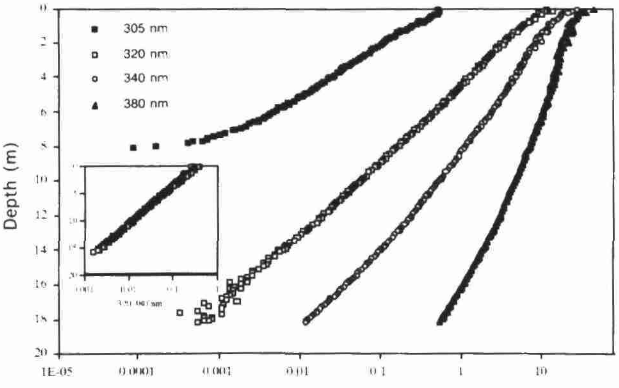

Fig. 1. Penetration of UV radiation of different wavelengths into the water column of the Northern Adriatic Sea measured on a cloudless day (16 July 96) at local noon. The inset shows the development of the ratio between 320 : 380 nm with depth. While the 320 nm wavelength represents the damaging wavelength range the 380 nm stands for the wavelength range used for inducing photoenzymatic repair. The ratio varies from 0 to 15 m depth over 3 orders of magnitude.