

EFFECT OF UV-B IRRADIANCE ON THE ATP CONTENT OF MICROORGANISMS OF THE WEDDELL SEA (ANTARCTICA)

J.H. VOSJAN¹, G. DÖHLER² and G. NIEUWLAND¹

¹Netherlands Institute for Sea Research, P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands

²Botanisches Institut der Universität Frankfurt, Siesmayerstr. 70, 6000 Frankfurt/Main 11, F.R.G.

ABSTRACT

The effect of UV-B irradiation on the ATP content of natural assemblages of planktonic microorganisms in the upper 30-m water layer of the Weddell Sea (Antarctica) was studied. After five hours of irradiation with UV (290-320 nm) of $1.35 \text{ W} \cdot \text{m}^{-2}$ a 75% decrease in the ATP content of the microorganisms was observed.

1. INTRODUCTION

The reduction of the stratospheric ozone layer by human pollution results in an increase in the solar UV radiation reaching the earth's surface. An enhanced UV level penetrating into the water column can lead to damage of living cells in the upper layer of the aquatic environment, resulting in *e.g.* inhibition of primary productivity, carbon and nitrogen metabolism as well as reduction in cell components (BAKER & SMITH, 1982; DÖHLER, 1985, 1989; HALL-DAHL, 1979; SMITH, 1989; WORREST, 1982, and references therein).

The photo-inhibition effect detected near the surface of the water in primary production measurements is caused by UV-A radiation, whereas the effect of UV-B is of minor importance according to BUHLMANN *et al.* (1987). However, less knowledge exists on the impact of UV-B on the biological systems of the Southern Ocean. In Antarctic waters with a low amount of particles and no yellow substance, the UV penetrates deeper (down to 50 m) (GIESKES *et al.*, 1989) than in more turbid waters. The transmittance of radiant energy of 310 nm in clear seawater exhibits maximum values of $86\% \cdot \text{m}^{-1}$ (JERLOV, 1976).

The microorganisms (bacteria, algae, protozoa) play a central role in the foodweb and in the carbon cycle of marine ecosystems. In biological oceanography the total microbial community is often quantified by measuring the adenosine-tri-phosphate (ATP) (KARL, 1980; VOSJAN & NIEUWLAND, 1987). This ATP is continuously formed in the catabolism and continuously used in all energy-consuming reactions of living organisms. So if there is any effect of UV-B ir-

radiance on the synthesis of ATP, it will be reflected in all other reactions of the organism. If there is an effect on anabolic synthesizing reactions it will also have its consequences for the biomass to be formed. This study assesses the effect of UV-B radiation on the ATP content of the microbial communities in the upper layer of the Weddell Sea.

Acknowledgements.—We thank the European Science Foundation and the Alfred-Wegener-Institute für Polar und Meeresforschung, Bremerhaven, FRG, for the opportunity to join the EPOS, leg 3 expedition to the Antarctic. This work was also supported by a grant of the Netherlands Marine Research Foundation (SOZ), The Hague, The Netherlands and a grant (KBF 56 B) from the Bundesministerium für Forschung und Technologie, Bonn, FRG.

2. METHODS

Water samples were taken with a Rosette sampler from the upper water layers to describe the ATP profile in the water column. The ATP content was estimated after the luciferine-luciferase method (VOSJAN, 1988). Without prefiltration all the organisms in the samples were concentrated on a $0.2 \mu\text{m}$ cellulose acetate filter and then extracted for the ATP analysis.

Experiments were performed with water samples from 2, 10 and 30 m depth of the stations 258 ($74^\circ 41.8' \text{ S}-29^\circ 23.8' \text{ W}$), 259 ($74^\circ 41.5' \text{ S}-29^\circ 4.9' \text{ W}$) and 260 ($74^\circ 39.1' \text{ S}-29^\circ 30.0' \text{ W}$) of the EPOS-III cruise in 1989 in the Weddell Sea. The samples were put into plexiglass cuvettes, which were illuminated in the laboratory with white light from one side and from the other side with ultraviolet (Philips, 12 TL, 20 W) at a distance of 20 cm from the cuvettes. Cut-off filter (WG 305, Schott & Gen., Mainz) was used for removing the shorter wavelengths of the UV. One cuvette was not UV-transparent and served as a control, whereas the other cuvette allowed penetration of UV-B light into the water sample. The intensity of the UV-B light (290-320 nm) was $1.35 \text{ W} \cdot \text{m}^{-2}$ as measured with International Light equipment (IL 1700; UV-B detector Nr. 5436) and that of the white light 240

$W \cdot m^{-2}$. Ambient solar UV radiation determined after the same procedure was $1.12 W \cdot m^{-2}$. The samples were stirred and bubbled with normal air and kept at $2^{\circ}C$. This is a few degrees above the *in situ* temperature. After 1/2 or 1 h adaptation the UV irradiation was started and every 1/2 h an aliquot of $10 cm^3$ was taken out of the cuvettes and the ATP content measured.

3. RESULTS AND DISCUSSION

The distribution of ATP in the organisms of the upper water layers of Halley Bay (Weddell Sea) is given in Fig. 1. The highest amount of ATP was found in the upper 20 m of the water column with values between 1100 and $1800 ng ATP \cdot dm^{-3}$, quickly decreasing to $\sim 300 ng \cdot dm^{-3}$ at 40 m depth. As a result of the very calm weather, the biomass of microorganisms was not mixed over a deep water column but accumulated in the upper few metres.

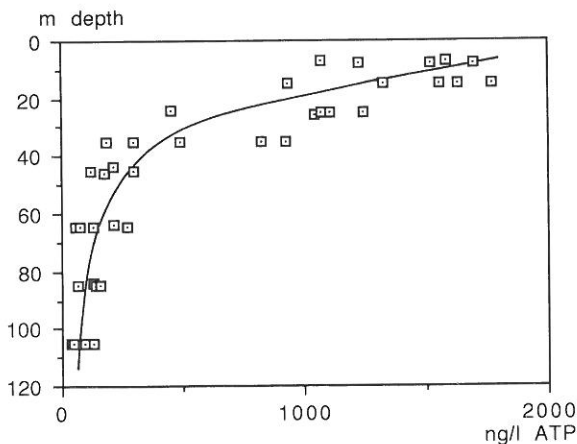


Fig. 1. ATP concentrations (in $ng \cdot dm^{-3}$) of the upper water column at various water depths (m) of Halley Bay (Weddell Sea) ($74^{\circ} 40' S$ - $29^{\circ} 30' W$).

The initial concentrations of ATP in the samples used for the experiments were between 270 and $650 ng \cdot dm^{-3}$. For our experiments we used the samples of 2, 10 and 30 m depth. Fig. 2 shows the ATP concentrations of the plankton collected at station 258 at 2 m depth in UV-B irradiated and non-UV treated samples plotted against exposure time. The aliquots of the non-UV transparent cuvette (control) showed a slight decrease in ATP concentrations. However, the ATP content of the plankton samples from the UV-transparent vessel decreased after 2 hours of UV-B radiation, and showed a strong reduction after longer UV-B exposure. After 5 hours of irradiance the rate of ATP decrease slowed down.

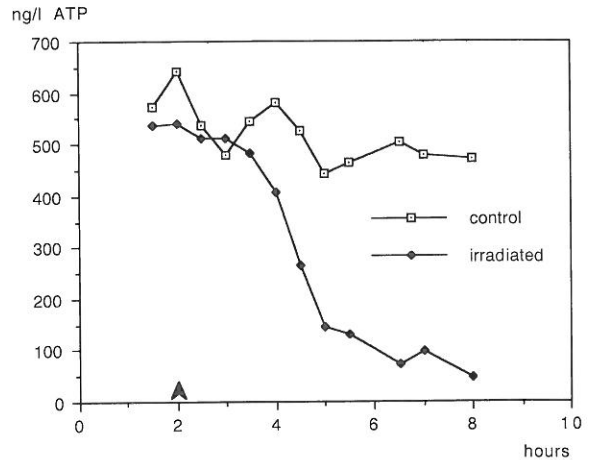


Fig. 2. The effect of UV-B irradiation on the ATP content of Antarctic plankton (station 258). The ATP concentrations of control and irradiated samples are plotted against irradiation hours. Arrow indicates start of irradiation.

Fig. 3 shows the percentages of the ATP content of the irradiated samples compared to the controls (=100%) at the same time. In 4 experiments with samples from the surface, 10 m and 30 m depths, on average a decrease of $\sim 75\%$ was found after 5 hours. The ATP content of the organisms in the UV-transparent cuvette, compared to the control, was reduced to 20, 26, 27, and 28% (average 25%). This clearly shows the damaging effect of UV-B irradiance on the ATP content of natural microbial populations.

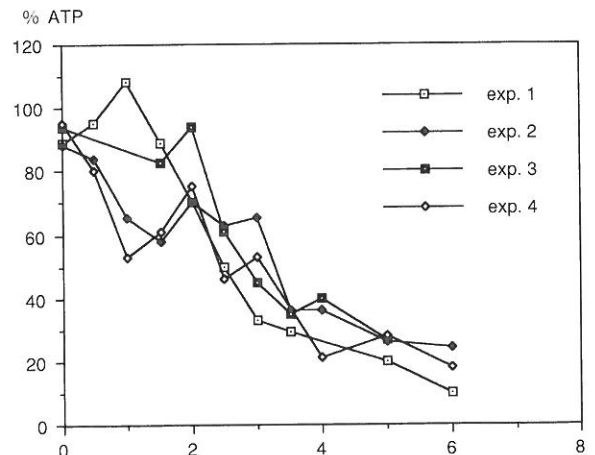


Fig. 3. ATP content of 4 irradiated samples given as percentages of the content of the controls, plotted against time (hours) of UV-B irradiation (stations 258, 259, 260).

However, the effect may not be so dramatic in the aquatic system itself because of lower irradiance levels in the water. By vertical movements of the particles in the upper mixed water layer the exposure

time of the microorganisms to UV fluctuates, particularly during stormy conditions. Severest damage would be expected during calm wind conditions, when the plankton is concentrated in the upper water layers.

Further studies on the amounts of UV radiation that organisms may receive in the upper mixed layer of the ocean and studies on the influence of UV-B radiation on organisms of the mixed layer will lead to more information on the consequences of UV radiation for the total microbial ecosystem. The above results are preliminary. Research about the natural levels of UV-B at different depths and locations is planned.

4. REFERENCES

- BAKER, K.S. & R.C. SMITH, 1982. Spectral irradiance penetration in natural waters. In: J. CALKINS. The role of solar ultraviolet radiation in marine ecosystems. Plenum Press, New York: 233-246.
- BUHLMANN, B., P. BOSSARD & U. UEHLINGER, 1987. The influence of longwave ultraviolet radiation (UV-A) on the photosynthetic activity (^{14}C -assimilation) of phytoplankton.—*J. Plankton Res.* **9**: 935-943.
- DÖHLER, G., 1985. Effect of UV-B radiation (290-320 nm) on the nitrogen metabolism of several marine diatoms.—*J. Plant Physiol.* **118**: 391-400.
- , 1989. Impact of UV-B radiation on nitrogen metabolism of marine phytoplankton. In: A.M. OZTURK. Plants and pollutants in developed and developing countries. Izmir, Turkey: 57-87.
- GIESKES, W.W.C., R. HEUSEL, G. KRAAY & M.M. TILZER, 1989. The underwater light climate.—*Ber. Polarforsch.* **62**: 75-83.
- HALLDAHL, P., 1979. Effect of changing levels of ultraviolet radiation on phytoplankton. In: A.K. Biswos. The ozone layer. Pergamon Press, Oxford: 21-34.
- KARL, D.M., 1980. Cellular nucleotide measurements and applications in microbial ecology.—*Microbiol. Rev.* **44**: 739-796.
- JERLOV, N.G., 1976. Marine optics. Elsevier, Amsterdam: 1-231.
- SMITH, R.C., 1989. Ozone, middle ultraviolet radiation and the aquatic environment.—*Photochem. Photobiol.* **50**: 459-468.
- VOSJAN, J.H., 1988. The ATP and ETS method in the study of surface layers and deep-sea basins of East Indonesian waters.—*Archs. Hydrobiol. Beih. Ergebn. Limnol.* **31**: 221-228.
- VOSJAN, J.H. & G. NIEUWLAND, 1987. Microbial biomass and respiratory activity in the surface waters of the East Banda Sea and North West Arafura Sea (Indonesia) at the time of the South East monsoon.—*Limnol. Oceanogr.* **32**: 767-775.
- WORREST, R.C., 1982. Review of literature concerning the impact of UV-B radiation upon marine organisms. In: J. CALKINS. The role of solar ultraviolet radiation in marine ecosystems. Plenum Press, New York: 429-457.

(received 26 January 1990; revised 10 April 1990)

