Photo-reversion caused by UV radiation: Life and the solar radiation on planetary environments with low ozone contents

H. Lammer[1], A. Bérces[2], G. Kovács[2], Gy. Rontó[23], N. K. Belisheva[4], C. S. Cockell[5], G. Kargl[1], N. I. Kömle[1] and H. K. Biernat[1]

[1]*Space Research Institute, Austrian Academy of Sciences, Schmiedlstr. 6, A-8042, Graz, Austria*
[2]*MTA-SE Research Group for Biophysics, H-1444 Budapest, P. O. Box 263, Hungary*
[3]*Institute of Biophysics and Radiation Biology, Semmelweis University, H-1444 Budapest, P.O. Box 263, Hungary*
[4]*Polar-Alpine Botanical Garden Institute, Russian Academy of Sciences, Fersman Street, 14, Apatity Murmansk Region, 184200 Russia*
[5]*British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK*

Solar UV radiation is the driving force for chemical- and organic- evolution but in certain doses may been dangerous for biological systems. So, the impact of UV radiation in low doses on human blood by auto-transfusion of UV irradiation produce diverse effects, which include the increasing of immune system resistance and the blood growth stimulating properties. At the same time the increased exposure of the human organism to UV radiation could be led to immune-suppression, eye damages, skin cancer-genesis, chromosomal aberrations in the organism cells. The dose of exposure of human organism to environmental UV radiation is connected with the geographical latitude, as well as with the concentration of stratospheric ozone. The depletion of ozone could led to an increasing of ground-level UV radiation exposure. To understand the role of UV radiation for organism functional state and the consequences of global, region and local depletion of stratospheric ozone for biosphere development it is necessary to compare the peculiarities of atmosphere in the past and present age, as so as to assess the biological effects of variations of genetically active UV with different wavelengths. Studies of the solar UV environment on early Earth 2.0 Gyr to 3.8 Gyr ago suggest that the terrestrial atmosphere was essentially anoxic, resulting in an ozone column abundance insufficient for protecting the planetary surface from the UV-B (280 nm – 315 nm) and the UV-C (200 nm – 280 nm) ranges. Since, short wavelength solar UV radiation in the UV-B and UV-C range penetrated to the Earth's surface across the oxygen-free unprotected atmosphere on the young planet, the trails of the impact of short wavelength solar UV radiation should be found in the biochemical behavior of the molecules, which must react on the same type at present as in the past. Similar biological effects could be expected over Earth's polar regions, due to the decreasing ozone-layer in the stratosphere. There are serious suppositions to consider (strong indications) that DNA and protein-based life was preceded by simpler life forms based primarily on RNA and prebiotic chemistry and activity in the pre-RNA world (uracil). Because it can be proposed, that prebiotic molecules (uracil) react on the impact of short wavelength solar UV radiation in a similar way as in the past, it can be used for studies of short wavelength UV radiation effects on molecules essential for life. For nucleic acid based UV dosimetry, bacteriophage T7, isolated phage-DNA and polycrystalline uracil samples have been used. The effect of solar UV radiation of short wavelength range on uracil in crystalline form is manifesting in the formation of the linkages between the molecules of uracil (dimmers) that can be considered as a model of nucleic acid damage due to the UV impact. Experimental evidence of suitability of such models for monitoring of UV radiation has been found in structure transformation of biomarker nucleic acid (bacteriophage T7, uracil thin layer), which manifested the selected sensitivity to the UV range. A kinetic radiation model (Ronto et al., 1967) demonstrate that UVC radiation can induce the direct opposite structure transformations of nucleic acid: dimerization and reversion of photoproducts (monomerization) by establishing an equilibrium of surviving (Fekete et al., 1998). The level of this equilibrium in such reaction depends on the induction rates in both directions, hence there is a chance for the existence of the whole DNA, or for the parts of DNA molecules to remain intact during UV exposure. Besides the results of photo-effects depend on the UV wavelength. Shorter UV wavelength (below about 220 nm) effective induces the monomerization, while more longer wavelength UV prefer produces the dimmers. A similar dependence of photo-reactivation on UV wavelength was shown for DNA synthetic activity in human embryo fibroblasts, growing in vitro (Zölzer et al., 1993). The nucleic acid effects induced by UV – photons in the short wavelength range could be imitate the state of organic substation during the time where living systems arise under an ozone-less atmosphere of the early Earth. The effect of solar UV radiation can be measured by detecting the biological-structural consequences of the damage induced by UV photons. We present and discuss experimental data, which show the photo-reverse effect of dimerized uracil molecules caused by shorter UV wavelengths. We show that shorter wavelength UV radiation of about 200 nm is strongly effective in monomerization, while the longer wavelengths prefer the production of dimerization. In the case of polychromatic light like in space or on a planetary surface, which is unprotected by an ozone layer the two processes run parallel. We could demonstrate experimentally, for the case of an uracil thin-layer that the photo-reaction process of the nucleotides can be both, dimerization and the reverse process: monomerization. This result is important for the study of solar UV exposure on organisms in ozone-free and ozone-decreasing (Earth's polar regions) planetary environments, since our experiments indicate that biological harmful effects can also be reduced by shorter wavelength UV radiation, which is of importance in reducing DNA damages provoked by longer wavelengths. Further, we discuss a longtime astrobiology experiment, which will take place on the European Space Agency's (ESA) second generation multi-user radiation exposure platform EXPOSE, presently developed for flight on the International Space Station (ISS).

Literature:

Rontó, Gy., S. Gáspár, P. Gróf, A. Bérces, Z. Gugolya (1994), Photochem. Photobiol. **59,** 209-214.

Fekete, A., A. A. Vink, S. Gáspár, A. Bérces, K. Módos, Gy. Rontó, L. Roza (1998), *Photochem. Photobiol*. **68,** 527-531.

Zölzer, F., N. K. Belisheva, V. L. Levin, K. A. Samoilova (1993), *J. Photochem. Photobiol. B* **18**, 87-89.