
The paradigm that failed

Zbigniew Jaworowski

Central Laboratory for Radiological Protection
ul. Konwaliowa 7, 03 194 Warsaw, Poland
E-mail: jaworo@clor.waw.pl

Abstract: About 2.3 billion years ago, the advent of an oxidative atmosphere, which was lethal for anaerobic biota, stimulated the surviving organisms to develop efficient defences against the enormous flux of Reactive Oxygen Species (ROS) produced by metabolic processes. Even earlier, similar defences were developed against the thermal instability of molecules and other events that damaged DNA. These powerful ancient defence mechanisms also protect the extant oxygen-loving organisms against the DNA damage caused by low levels of ionising radiation, which is one of the smallest risks in the environment, and contributes just a tiny fraction to the spontaneous rate of the DNA-damaging events. In this perspective, the Linear No Threshold (LNT) model of the radiation effects appears inappropriate for the current needs. Because of statistical reasons, it cannot be falsified. On the other hand, the hormetic model has the capacity to be tested in the observable zone. The precautionary principle, an offspring of LNT, leads to unacceptable societal penalties, as demonstrated in the aftermath of the Chernobyl catastrophe.

Keywords: efficient defences; reactive oxygen species; ROS; metabolic processes; thermal instability; DNA damage; low levels of ionising radiation; linear no threshold model; hormetic model; societal penalties; Chernobyl aftermath.

Reference to this paper should be made as follows: Jaworowski, Z. (2008) 'The paradigm that failed', *Int. J. Low Radiation*, Vol. 5, No. 2, pp.151–155.

Biographical notes: Zbigniew Jaworowski, MD, PhD, DSc, is a Professor Emeritus of the Central Laboratory for Radiological Protection in Warsaw, Poland, a member of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and its former Chairman. He is the President of the Association of Environmentalists for Nuclear Energy (EFN), Poland. His research fields are radiotoxicology, radiobiology, nuclear emergencies, the historical monitoring of radionuclides and heavy metals in humans in the past 5000 years, the temporal and geographical distribution of pollutants in the global troposphere and stratosphere and the validity of the ice core records for the reconstruction of the past chemical composition of the atmosphere and climate. He has published more than 300 scientific papers, four books and one patent.

1 Introduction

We are all immersed in a sea of ionising radiation that penetrates the biosphere, the innermost parts of the Earth and the whole universe. This type of radiation was discovered in relatively recent times (at the end of the 19th century), but it was always

with us. Yet, ionising radiation is treated by many with an exotic connotation and as fundamentally different from other forms of energy. This distinction, which has serious negative consequences, is not scientifically based, but instead has philosophical and political roots (Taylor, 1980). The distinction stems in part from our short acquaintance with radiation and from the lack of a specific radiation-sensing organ. Living organisms have no such organ because it is unnecessary: radiation is one of the smallest risks they encounter almost all over the biosphere and its natural level is, and always was, much below lethal doses. The only exceptions were the insides of the natural Oklo-type underground nuclear reactors, a phenomena of utmost rarity (Draganic *et al.*, 1993).

When life started on Earth about 3.9 billion years ago, the level of radiation was some five times higher than today (Karam and Leslie, 1999). Living organisms adjusted to it, as they did to all other forms of energy. The adjustment took two forms: one used it for the benefit of the organisms, as is demonstrated by the ubiquitous phenomenon of radiation hormesis (Calabrese and Baldwin, 2000; 2001; Jaworowski, 1995; 1999; Luckey, 1991; Pollycove and Feinendegen, 2001) and by experiments suggesting that ionising radiation may be essential for life (Planel *et al.*, 1987). The second involved the development of the systems protecting the organism against the noxious effects of ionising radiation.

2 Radioadaptation: evolution and impact

At the dawn of life, the level of oxygen in the atmosphere and the oceans was extremely low. The dramatic rise of the oceanic and atmospheric oxygen about 2.3 billion years ago (Bekker *et al.*, 2004) was caused by a mass blooming of cyanobacteria, induced by a change from an extremely cold climate (a 'Snowball Earth') into a warm one. The change from anoxic into oxic conditions was probably the greatest catastrophe in the history of life, since oxygen was a deadly poison for the anaerobic organisms that had dominated Earth before this event. It was at that time that the organisms developed extremely efficient defences against Reactive Oxygen Species (ROS), the main culprits in the radiation damage to the DNA, along with similar defences – probably developed earlier – against the damaging effects of the thermal instability of molecules and the enzymatic processes. Most of the anaerobic species that did not adjust to a new environment died out, with the few that survived the cataclysm hiding in oxygen-free niches. Those that adjusted were exposed to an enormous stream of metabolic ROS formed in each cell at a rate of about 3×10^{16} per cell per year (Sen *et al.*, 2000). This stream, together with the thermal and enzymatic effects, caused about 70 million spontaneous DNA damages per year in each mammalian cell (Billen, 1994). Only if armed with a powerful defence system, living organisms could survive such a high rate of natural DNA damage. The extant oxyphilic organisms developed the sophisticated protective mechanisms against ionising radiation as a side product of the defence against the toxicity of oxygen and against the noxious thermal and enzymatic effects. It is only in the last two decades that we have started to discover these mechanisms (see a recent review of Feinendegen *et al.* (2006). One of the factors stimulating these studies was a publication of a path-breaking document of the United Nations Scientific Committee on the Effects of Atomic Radiation on the adaptive responses to the radiation in cells and organisms (UNSCEAR, 1994).

The average level of ionising radiation (about 2.4 mSv per year) contributes just a tiny fraction to the spontaneous rate of DNA-damaging events: about five events in one cell per year. Such a minute increment of DNA damage from the low doses of radiation does not impose a significant risk. That risk only becomes significant at high doses, when the DNA repair capacity is exceeded. This capacity is high above the current dose limit for the general population of 1 mSv per year (ICRP, 1990), which corresponds to about two DNA damages per cell per year (Billen, 1994; Stewart, 1999) out of about 70 million natural ones. Such a disproportion between the regulations and biological reality leads to disastrous practical consequences such as mass scale radiophobia, the lack of confidence in the medical applications of radiation, the virtual strangulation of the development of nuclear energy in many countries and the enormous wasteful costs of superfluous radiological protection. A tragic example includes the mass psychosomatic disorders and the unnecessary relocation of some 336 000 people after the Chernobyl accident in areas where the average radiation dose rate from the Chernobyl fallout was 0.8 to 1.4 mSv per year above the average natural level of 2.4 mSv per year (UNSCEAR, 2000). It is estimated that about five million people were needlessly affected by the stressful post-Chernobyl legislation based on the ICRP recommendations (Filyushkin, 1996). The radiation level in the areas of relocation was much lower than from the natural background radiation in many regions in Brazil, Europe, India and Iran. The areas of relocation were defined as ‘contaminated regions’, starting with a level of radioactive cesium in the ground at 37 kBq/m², which is ten times lower than the average level of natural radioactive nuclides in a 10-cm thick layer of soil (400 kBq/m²) (Jaworowski, 2004). The relocations inflicted incalculable suffering, social degradation and impoverishment on these people. Obviously, the ICRP will never accept responsibility for the disastrous effects of the practical application of its elucubrations, which make that the present, based on the Linear No Threshold (LNT) principle system of “radiation protection becomes a health hazard” (Walinder, 1995).

In the wake of the Chernobyl catastrophe, we witnessed a mischievous use of the numbers game in calculating the numbers of people who will purportedly die due to irradiation with doses not much higher than the average global natural radiation dose, or even exposure to tiny fractions of this dose. Such a game, based on the LNT principle, was played by many individuals and international bodies. More recent examples of such estimates range from 4000 cancer deaths projected by the United Nations political and scientific body (Chernobyl Forum, 2005) to six million deaths projected by Greenpeace (Yablokov *et al.*, 2006). Dr. Lauriston S. Taylor, the coryphaeus of radiological protection, defined such procedures as “deeply immoral uses of our scientific heritage” (Taylor, 1980).

3 Conclusion

The inappropriateness of the radiation standards for the current needs is reflected in the vast difference between their foundation – *i.e.*, the genetic data from the radiological experiments in the 1950s and the assumptions supporting the LNT model – and the recent overwhelming tide of progress in genetics, radiobiology, toxicology and experimental oncology. The weakness of the more than 50-year-old LNT model is of the ‘trans-science’ character: as for any other environmental factor, one can never prove

that ionising radiation is totally harmless (Weinberg, 1972). This is an analogy to the famous statement of Bertrand Russell that one cannot disprove faith that a China teapot is orbiting the Sun between the Earth and Mars. The presence of this teapot is hypothetical and that hypothesis, similar to LNT, cannot be disproven (Russell, 1952). On the other hand, a great strength of the hormetic model is that it has the capacity to be tested in the observable zone, both experimentally and epidemiologically (Cook and Calabrese, 2006; Webster, 1993).

The outdated genetic experiments standing behind the LNT model and the current regulations are in disagreement with the findings from Hiroshima and Nagasaki, where no adverse genetic effects were found in the children of the highly irradiated survivors of the nuclear attacks (UNSCEAR, 2001). The 'precautionary principle', reducing the exposures ever lower and at any cost, proved not to be 'cautionary' at all. It has led to unacceptable societal penalties, as clearly demonstrated in the aftermath of the Chernobyl catastrophe. The time has come to change the lithified LNT paradigm and to base radiological safety and protection on modern knowledge and the realities of the natural radiation environment.

References

- Bekker, A., Holland, H.D., Wang, P-L., Rumble, D.I., Stein, H.J., Hannah, J.L., Coetzee, L.L. and Beukes, N.J. (2004) 'Dating the rise of atmospheric oxygen', *Nature*, Vol. 427, 8 January, pp.117–120.
- Billen, D. (1994) 'Spontaneous DNA damage and its significance for the "negligible dose" controversy in radiation protection', *BELLE Newsletter*, Vol. 3, No. 1, pp.8–11.
- Calabrese, E.J. and Baldwin, L.A. (2000) 'Radiation hormesis: its historical foundations as a biological hypothesis', *Human & Experimental Toxicology*, Vol. 19, No. 1, pp.41–75.
- Calabrese, E.J. and Baldwin, L.A. (2001) 'Special issue: scientific foundations of hormesis', *Critical Reviews in Toxicology*, Vol. 31, Nos. 4–5, pp.347–695.
- Chernobyl Forum (2005) 'Chernobyl's legacy: health, environmental and socio-economic impacts and recommendations to the governments of Belarus, the Russian federation and Ukraine', *The Chernobyl Forum*, pp.1–57.
- Cook, R. and Calabrese, E.J. (2006) 'The importance of hormesis to public health', *Environmental Health Perspectives*, Vol. 114, No. 11, pp.1–5.
- Draganic, I.G., Draganic, Z.D. and Adloff, J-P. (1993) *Radiation and Radioactivity on Earth and Beyond*, CRC Press.
- Feinendegen, L.E., Pollycove, M. and Neuman, R.D. (2006) 'Whole body responses to low-level radiation exposure. New concepts in mammalian radiobiology', *Experimental Hematology*, Vol. 35, No. 4, pp.37–46.
- Filyushkin, I.V. (1996) 'The Chernobyl accident and the resultant long-term relocation of people', *Health Physics*, Vol. 71, No. 1, pp.4–8.
- ICRP (1990) *1990 Recommendations of the International Commission on Radiological Protection*, Pergamon Press.
- Jaworowski, Z. (1995) 'Stimulating effects of ionizing radiation: new issue for regulatory policy', *Regulatory Toxicology and Pharmacology*, Vol. 22, pp.172–179.
- Jaworowski, Z. (1999) 'Radiation risk and ethics', *Physics Today*, Vol. 52, No. 9, pp.24–29.
- Jaworowski, Z. (2004) 'Chernobyl, nuclear wastes and nature', *Energy & Environment*, Vol. 15, No. 5, pp.807–824.
- Karam, P.A. and Leslie, S.A. (1999) 'Calculations of background beta-gamma radiation dose through geologic time', *Health Physics*, Vol. 77, No. 6, pp.662–667.

- Luckey, T.D. (1991) *Radiation Hormesis*, CRC.
- Planel, H., Soleilhavoup, J.P., Tixador, R., Richoilley, G., Conter, A., Croute, F., Caratero, C. and Gaubin, Y. (1987) 'Influence on cell proliferation of background radiation or exposure to very low, chronic gamma radiation', *Health Physics*, Vol. 52, No. 5, pp.571–578.
- Pollycove, M. and Feinendegen, L.E. (2001) 'Biologic responses to low doses of ionizing radiation: detriment versus hormesis. Part 2: Dose responses of organisms', *The Journal of Nuclear Medicine*, Vol. 42, No. 9, pp.26N–32N.
- Russell, B. (1952) 'Russell's teapot', *Wikipedia*, http://en.wikipedia.org/wiki/Russell's_teapot.
- Sen, K., Sies, H. and Baeurle, P. (Eds.) (2000) *Redox Regulation of Gene Expression*, Academic Press.
- Stewart, R.D. (1999) 'On the complexity of the DNA damages created by endogenous processes', *Radiation Research*, Vol. 152, pp.101–105.
- Taylor, L.S. (1980) 'Some non-scientific influences on radiation protection standards and practice', *Health Physics*, Vol. 32, pp.851–874.
- UNSCEAR (1994) 'Sources and effects of ionizing radiation', *Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. Annex B: Adaptive Responses to Radiation in Cells and Organisms*, United Nations.
- UNSCEAR (2000) 'Sources and effects of ionizing radiation', *United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000, Report to the General Assembly, with Scientific Annexes*, United Nations, p.1220.
- UNSCEAR (2001) 'Hereditary effects of radiation', *UNSCEAR 2001 Report to the General Assembly, with Scientific Annex, United Nations Scientific Committee on the Effects of Atomic Radiation*, p.224.
- Walinder, G. (1995) *Has Radiation Protection Become a Health Hazard?*, The Swedish Nuclear Training & Safety Center.
- Webster, E.W. (1993) 'Hormesis and radiation protection', *Investigative Radiology*, Vol. 28, No. 5, pp.451–453.
- Weinberg, A.M. (1972) 'Science and trans-science', *Minerva*, London, Vol. 10, pp.209–222.
- Yablokov, A., Labunska, I., Blokov, I., Santillo, D., Johnston, P., Stringer, R. and Sadownichik, T. (Eds.) (2006) 'The Chernobyl catastrophe', *Consequences on Human Health – GREENPEACE 2006*, Greenpeace, pp.1–139.