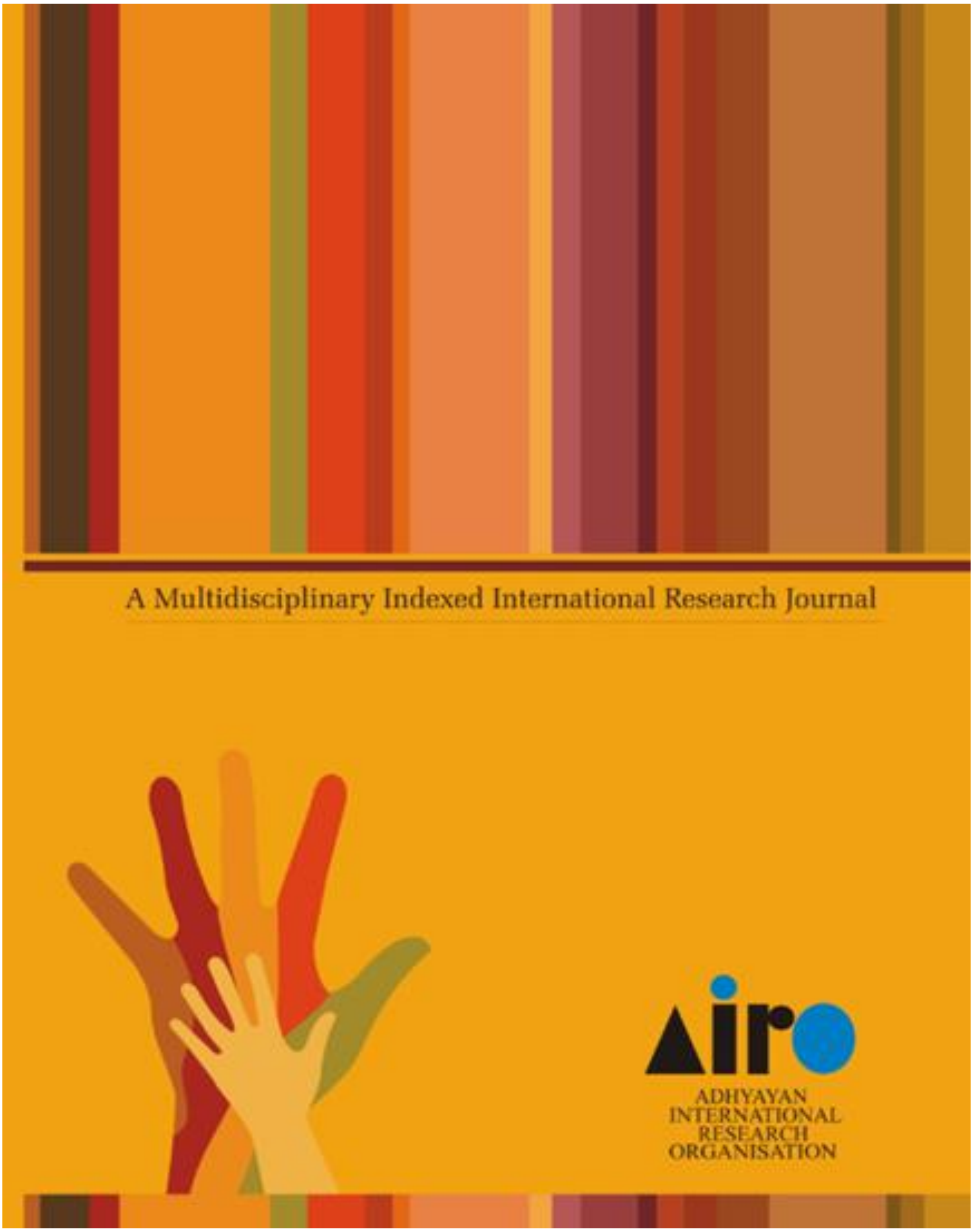
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MECHANISMS OF RADIATION TOLERANCE IN FRUIT FLY DROSOPHILA

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ABSTRACT

Radiation is a form of energy generated during nuclear interactions of unstable atoms. This process is called as radioactive disintegration. The elements undergoing the process of radioactive disintegration are radionuclides. Radiation travels in a wave form or as energized particles. Ever since the formation of the universe radiation exists, and our knowledge of radiation is a century old. Research in the field of radiation started after the discovery of X-rays by W. C. Roentgen in 1895 and the phenomenon of radioactivity by A. H. Becquerel in 1896. Radiation is present throughout our planet, and we call it background radiation. Background radiation comes from naturally occurring minerals in soil, water, buildings, and it is also present in our bodies. Levels of background radiation on earth change from place to place and with altitude.

Keywords: Radiation, energy

INTRODUCTION

Human exposure to radiation energy is not new. Abandoned radioactive waste materials caused radiation poisoning and have led to several tragedies. Ignorance/unawareness caused many casualties in early years of its discovery. Female factory workers in dial painting industry used saliva to sharpen the brush for painting dials with radium paint. They also painted their finger nails and teeth with radium. Many of the women later began to suffer from anemia, fractures and necrosis of the jaw, a condition now known as radium jaw (Rowland 1994).

Coal mine workers in hard rock mines of Saxony died early from lung disease. More than 20 years before radioactivity was detected, an epidemiological study in Schoenberg in 1876 identified this lung disease as lung cancer (Maurya et al., 2011).

Exposure of workers to an unknown carcinogenic agent in the air of the mines was the reason for development of this disease. In modern life increased use of radiation, in the healthcare sector for diagnosis and treatment (White and Mallya 2012), in the agriculture sector for generating transgenic plants and for pest control, in scientific research, during security checks and in nuclear power plants for energy generation, has increased the possibilities of human exposure to radiation (Eyre 1996).

LITERATURE REVIEW

High energy radiation has found applications in various fields. In healthcare, radiation is used to monitor, diagnose and treat medical conditions. Diagnostic applications include use of radioactive isotopes such as131I, 32P, 59Fe, 51Cr, and 60Co, (Casarett 1968). Diagnostic practices include use of X-rays for diagnosis of fractures, for computed tomography (CT) to observe shapes and details of internal organs and in cancer diagnosis. X-rays are also used to show structural changes during dental care (White and Mallya 2012). Radiotherapy is a common practice in cancer treatment and includes use of radionuclides for targeting cancerous tissue (Casarett 1968).

In the food industry, radiation is used for preventing sprouting of seeds, disinfection of grain from insects, sterilization against bacteria and microorganisms (Casarett 1968). Radiation treatment improves storage life, hygiene and safety. The microbiological, nutritional and chemical nature of radiation-processed foods has been studied in detail. No study has indicated any adverse effects of radiation on food quality (Casarett 1968).

In nuclear power plants for power generation, energy released by fission of 235U or plutonium is used to generate electricity. Gauges with radioactive substances are used to measure the thickness of paper products, fluid levels in pipes and chemical tanks, and the moisture and density of soil and other material at construction sites. Radiography is used to check the flow of oil in sealed engines. Radiation is also used to remove toxic pollutants, such as exhaust gases from coal-fired power stations and industries (Casarett 1968, Arena 1971).

In the agricultural sector radiation is also used to generate new plant varieties with high yielding and disease resistant capacities. Seeds are exposed to bring about new and better types of plants. Radiation is also used to control insects, thereby decreasing the use of dangerous pesticides (Arena 1971).

RADIATION EFFECTS

Bystander effects

Bystander effects are biological effects in an unirradiated organism which occur indirectly in response to ionizing radiation. It has been demonstrated that radiation responses or damage in biological tissue or a cell occur both in tissue/cells exposed to ionizing radiation or in nearby tissue/cells. When the responses occur in the cells or the tissue which are not irradiated but are present in the vicinity to the irradiated cell or tissue, such effects are called Bystander effects (Hall 2003). Several in vivo studies using mice models have shown that the non-targeted effects occur post-irradiation with low energy transfer LET radiation. The bystander effects are non-targeted effects and occasionally these responses are found advantageous to the organisms. However available literature about bystander effects is insufficient to explain the magnitude of bystander effects post-irradiation and whether they are beneficial or harmful (Held 2009).

Radiation hormesis

Radiation hormesis is a phenomenon in which ionizing radiation, when delivered in low doses to a tissue or a cell, is found to stimulate beneficial effects. Einstein (2012) reported that activation of certain pathways and some signaling mechanisms which are not active without exposure to ionizing radiation induce responses in specific target tissues e.g. immunological responses and activation of certain growth factors. The low dose exposure stimulates certain repair pathways involved in DNA damage prevention. The study also reported the stimulation of immune responses post-irradiation at low doses (Einstein 2012).

Besides useful applications ionizing radiation has harmful side effects as well. In the early days of use of radiation in various sectors led to devastating effects due to lack of knowledge about long term deleterious effects of radiation. The Radium Girls and miners of Saxony are classic examples of effects of radiation hazards. Tragic incidences like Chernobyl and Fukushima led to leakage of radioactive substances into the environment exposing humans, animals and agricultural products to radioactive material. After the Chernobyl tragedy anemia was generally observed in the local population. Skin burns and severe skin injuries were common due to contamination with radioactive fission products (Maurya et al., 2011). In the years following the Chernobyl accident drastic increases in thyroid cancer (Cardis et al., 2006) and childhood leukemia (Parkin et al., 1996) cases were observed.

Following ionizing radiation exposure there are two types of health effects: deterministic and stochastic (Probalistic). The deterministic effects (e.g.: cataract induction, hematologic deficiencies, erythema, damage to skin and fertility impairment) are manifested due to exposure to high dose radiation or an exposure to a threshold dose required to induce these effects (Casarett 1968). Damage to DNA is a result of ionizing radiation exposure, and it is one of the important factors in cell death. Post-irradiation several responses are seen, such as altered cell division, depletion of stem cells, organ system dysfunction, and, if the radiation dose is adequately high, the organism may eventually die. Exposure to high doses of ionizing radiation causes tissue dysfunction in a dose-dependent manner; damage to the hematopoietic, gastrointestinal, reproductive and central nervous systems are common in higher eukaryotic systems (Yamini et al., 2010). Deterministic effects are related to cell death, whereas the stochastic effects are delayed effects (e.g. cancer appearing several years after exposure to ionizing radiation) and are usually seen as a side effects of diagnostic or theoretic treatments.

The severity of stochastic effects is independent of the dose used for treatments/diagnosis. They are usually characterized by radiation-induced mutations rather than cell death (Einstein 2012).

Radiation effects in a biological tissue vary with factors such as exposure time, distance from the source, dose, dose rate and tissue type (Casarett 1968; Granier and Gambini 1990).At low doses ionizing radiations were reported to show beneficial effects, a phenomenon referred to as radiation hormesis, whereas at high doses the effects were damaging to biological material. Ionizing radiation damages biological tissue in two possible ways, direct effects and indirect effects (Figure 1.2). The direct damages following irradiation are small in proportion to damages through indirect effects of ionizing radiation (Hall 1994).

Direct effects

Direct effects involve high linear energy transfer (LET) of radiation energy directly to the biological tissue or a molecule. The high LET radiation have sufficient energy to knock off the electrons in bio-molecules, which renders the bonding in a molecule susceptible for breakage. Therefore, when the high LET radiation falls directly on a molecule, it leads to formation of ionized species in the form of daughter molecules, and it ultimately damages the bio-molecule. When DNA absorbs high energy LET radiation, it suffers severe damage. Postirradiation single-strand and double-strand breaks are common in DNA molecules, and some oxidative modifications in nucleotide bases such as, 8-oxo-guanine formation from guanine are common. The damages caused by a direct mode of action of ionizing radiation are comparatively less in number than the damages caused by an indirect mode of action, but these damages (single and double strand breaks) can be lethal if the repair system is error-prone or inefficient to overcome such damages.

Indirect effects

Indirect effects of radiation occur through the formation of reactive oxygen species (ROS). The biological tissues consist of small molecules (e.g. amino acids, sugars etc.) and these are considered as building blocks of life. Besides small molecules, biological systems primarily consist of water molecules, which surround to the vital bio-molecules. Therefore, effects of radiation are appearing as a result of radiolysis of water (Wang et al., 2010). Postexposure to ionizing radiation these water molecules undergo radiolysis and lead to generation of free hydroxyl and superoxide radicals. These radicals interact with bio-molecules and result in their oxidative modification. The free radicals formed are not long-lasting species, and they instantaneously interact with molecules in their vicinity. The damage caused by an indirect mode of interaction post-irradiation accounts for about 75 % of all damage (Murley et al., 2006). The low LET ionizing radiation used in the health care sector during diagnostic and treatment procedures exerts cytotoxic effects largely through an indirect mode of action by generating free radicals. Free radicals have the capability to damage bio-molecules at different frequencies. The extent of damage to bio-molecules by free radicals varies. Double- and singlestrand breaks in DNA also vary with the dose of radiation. Double-strand breaks are 20 to 40 per cell/Gy, single-strand breaks are 1000 per cell/Gy, and oxidative base modifications are up to 1000 per cell/Gy (Upton 1992, Calabrese et al., 2002, Hall 2006). Free radicals generated from water radiolysis initiate a cascade of reactions and generate additional free radicals. These radicals have molecular specificity up to a certain extent. Experiments have suggested that the hydroxyl radical (OH•) is primarily responsible for damages to the DNA. This may be because OH• radicals are highly reactive among all free radicals and they have a high rate of reaction (Siddiqi and Bothe 1987, Milligan et al., 1993).

RADIOLYSIS OF WATER

Almost all biological tissues consist of a large quantity (80%) of water. The presence of water ensures radiation damage. Radiation effects in aqueous systems were reported in radium salt solution by Curie and Debierne in 1901 (Casarett 1968). Post-irradiation aqueous solution produces highly reactive species. As a result, molecules present in solutions undergo chemical modifications. These reactive species are the product of radiolysis of water molecules. The common reactive species are e - aq, HO• , H• , H2 and H2O2 and are produced during radiolysis of water (Abou-Seif et al., 2003, Riley 1994) by the following reactions:

$$3H_2O \rightarrow e^-_{aq} + H^\bullet + 2HO^\bullet + H_3O^+$$

$$2H^\bullet + 2O_2 \rightarrow HO_2^\bullet \rightarrow H^+ + O_2^{\bullet-}$$

$$e^-_{aq} + O_2 \rightarrow O_2^{\bullet-}$$

$$2O_2^{\bullet-} + 2H^+ \rightarrow O_2 + H_2O_2$$

The free radicals generated due to radiolysis of water can damage vital molecules and induce the production of a variety of other radicals, which later act on bio-molecules.

CONCLUSION

Free radicals generated by the radiolysis of water can last only for a few nanoseconds, but can cause serious damage to the molecules in their vicinity. The formation of these oxidative radicals and their cascading effects depend on several factors such as the nature of the radiation, time of exposure, and the concentration of dissolved oxygen and organic matter present.

REFERENCES

[1]. Maurya, D. K., &Devasagayam, T. P. A. (2011). Role of radioprotectors in the inhibition of DNA damage and modulation of DNA repair after exposure to gamma-radiation. Selected Topics in DNA Repair. Prof. Clark

Chen (Ed.), ISBN: 978-953-307-606-5, InTech.

[2]. Eyre, B. L. (1996). Industrial applications of radiation, radiation protection dosimetry. Nuclear technology publishing; 68(1/2): 63-72.

[3]. Casarett, A. P. (1968). Radiation biology. Prentice-Hall, Englewood Cliffs, New Jersy

[4]. White, S. C., &Mallya, S. M. (2012). Update on the biological effects of ionizing radiation, relative dose factors and radiation hygiene, Australian Dental Journal. 57(1): 2–8.

[5]. Arena, V. (1971). Ionizing radiation and life: An introduction to radiation biology and biological radiotracer methods. Saint Louis: Mosby.

[6]. Hall, E. J. (2003). The bystander effect. Health Phys., 85(1), 31–35.

[7]. Held, K. D. (2009). Effects of low fluences of radiations found in space on cellular systems. International Journal of Radiation Biology, 85(5), 379–390.

[8]. Einstein, A. J. (2012). Effects of radiation exposure from cardiac imaging: How good are the data? Journal of the American College of Cardiology, 59(6), 553–565

[9]. Cardis, E., Howe, G., Ron, E., Bebeshko, V., Bogdanova, T., Bouville, A., Carr, Z., Chumak, V., Davis, S., Demidchik, Y., Drozdovitch, V., Gentner, N., Gudzenko, N., Hatch, M., Ivanov, V., Jacob, P., Kapitonova, E., &Kenigsberg, Y. (2006). Cancer consequences of the Chernobyl accident : 20 years on. J. Radiol. Prot, 26, 127–140.

[10]. Yamini, K., & Gopal, V. (2010). Natural radioprotective agents against ionizing radiation - an overview. International Journal of PharmTech Research, 2(2), 1421–1426.

[11]. Calabrese, E. J., & Baldwin, L. A. (2002). Defining hormesis. Human and Experimental Toxicology, 21(2), 91–97.

[12]. Hittelman, W. N., Liao, Y., Wang, L., &Milas, L. (2010). Are cancer stem cells radioresistant? Future Oncology, 6(10), 1563–1576

[13]. Murley, J. S., Kataoka, Y., Weydert, C. J., Oberley, L. W., &Grdina, D. J. (2006). Delayed radioprotection by nuclear transcription factor kappaB -mediated induction of manganese superoxide dismutase in human microvascular endothelial cells after exposure to the free radical scavenger WR1065. Free Radical Biology & Medicine, 40(6), 1004–1016.

[14]. Siddiqi, M. A., & Bothe, E. (1987). Single- and double-strand break formation in DNA irradiated in aqueous solution: dependence on dose and OH radical scavenger concentration. Radiat. Res., 112(3): 449-463.

[15]. Milligan, J. R., Aguilera, J.A., & Ward, J. F. (1993). Variation of single-strand break yield with scavenger concentration for plasmid DNA irradiated in aqueous solution. Radiat. Res.,133(2),151-157

[16]. Abou-Seif, M. A. M., El-Naggar, M. M., El-Far, M., Ramadan, M., & Salah, N. (2003). Amelioration of radiation-induced oxidative stress and biochemical alteration by SOD model compounds in pre-treated γ-irradiated rats. ClinicaChimicaActa, 337(1–2), 23–33.

[17]. Riley, P. A. (1994). Free radicals in biology: Oxidative stress and the effects of ionizing radiation. International Journal of Radiation Biology, 65(1), 27–33.