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Is a base level of radiation essential for human health?

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Abstract
Over billions of years, life has evolved under the constant influence of low-level background radiation, raising an interesting question of whether a base level of radiation is essential for maintaining biological health. This paper examines the radiation hormesis hypothesis, which posits that low-dose ionising radiation (LDIR) is essential to maintaining health. The paper will examine experimental studies to assess the implications of LDIR for both terrestrial health and relate this to future long-term space exploration.

Keywords: *Health; Biology; Physics, Space Exploration; Radiation Hormesis; LDIR; Cellular Processes*

Introduction
Humans, like all life on Earth, have evolved in an environment with low background radiation (~2.4 mSv/year) from cosmic rays, terrestrial sources and internal isotopes [1]. While these levels are generally harmless, an intriguing question arises: Is a baseline level of radiation essential for human health? This concept, known as radiation hormesis, is an active area of research, particularly relevant for long-term space exploration, where radiation exposure is a critical factor alongside gravity, nutrition, hydration, and respiration.

Radiation Hormesis
Radiation hormesis proposes that low-dose ionising radiation (LDIR), such as Earth's background radiation, may not only be beneficial but is essential for life that has evolved in its presence [2]. This hypothesis remains contentious, with critics citing limited conclusive evidence. However, a growing body of research supports the physiological importance of hormetic LDIR responses in biological systems [2, 3]. Understanding these effects is particularly relevant for long-term space exploration, where controlled radiation exposure may play a role in astronaut health. A comprehensive review of existing studies and targeted research are essential to address knowledge gaps and advance human space exploration.

1980s Protozoan Experiment
Luckey (1986) investigated the reproduction and growth of *Tetrahymena pyriformis* under varying radiation levels using a ceasium-137 (^{137}Cs) source within a lead-shielded box [3, 4, 5]. Over six days, below-background radiation reduced growth and reproduction, while LDIR above background enhanced both. Subsequent studies have corroborated these findings, reinforcing interest in LDIR's biological effects.

2004 Study on the Effects of LDIR on Bone Marrow Stem Cells in Mice
Li *et al.* (2004) identified 75 mSv as the optimal LDIR dose for stimulating hematopoietic progenitor cell (HPC) proliferation and mobilisation in mice. Increased expression of colony-stimulating factors (G-CSF, GM-CSF) and cytokines (IL-3) enhanced hematopoietic repopulation in lethally irradiated recipients, highlighting potential clinical applications for improving hematopoietic recovery in chemotherapy patients [4, 6].

2015 Review into the Effect of LDIR on luminous marine bacteria
Kudryasheva & Rozhko (2015) comprehensively reviewed studies on LDIR effects in luminous marine bacteria exposed to hydrogen 3 (^{3}H), Americium 241 (^{241}Am), uranium 235 and 238 (^{235}U and ^{238}U) in aqueous media. Their analysis revealed adaptive responses consistent with radiation hormesis,

following a non-linear dose-response pattern with three phases: no observable effect, activation, and inhibition at higher doses [4, 7].

2015 Study into Lung Cancer Hormesis

Lehrer & Rosenzweig (2015) analysed lung cancer incidence in states with varying radiation exposure, comparing those with nuclear testing history (high-impact) to those with lower exposure (low-impact) (fig 1). Using data from the American Cancer Society, they found lower lung cancer rates in high-impact radiation states, suggesting that LDIR may have a protective effect rather than promoting cancer development [4, 8].

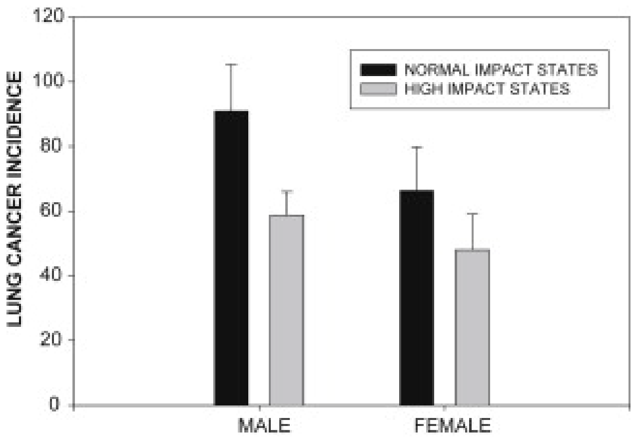

Figure 1 – Lung Cancer rates in high vs low impact radiation states [7].

Benefits and Risks of Radiation Hormesis

Numerous studies suggest LDIR benefits biological health, with some proposing it is essential for life on Earth, while others argue its effects are response-driven rather than dose-dependent [2, 3, 4, 6, 7, 8, 9]. Key benefits of LDIR-induced hormesis include:

1. ***Neuroprotection*** – Mitigating amyloid-β1-42-induced cell death via Akt and p38 pathway regulation in Alzheimer's disease.
2. ***Protein Homeostasis*** – Enhancing protein folding through molecular chaperone upregulation.
3. ***Enzyme Activation*** – Improving catalytic efficiency, supporting DNA repair, metabolism, and energy production.
4. ***Antioxidant Defense*** – Boosting glutathione peroxidase (GPx), superoxide dismutase (SOD), and catalase (CAT) activity.

Collectively, these effects enhance immune function, strengthen cellular repair, and improve metabolic efficiency, potentially reducing susceptibility to infections and disease [2, 10, 11]. While some research supports LDIR's health benefits, other studies suggest potential risks, including but not limited to [2, 4, 12, 13, 14, 15]:

1. ***Carcinogenesis*** – Elevated risk of various cancers.
2. ***Genotoxicity*** – DNA damage and mutations, potentially leading to generational health effects.
3. ***Cellular and Molecular Damage*** – Protein impairment and altered blood chemistry.
4. ***Cardiovascular Risks*** – Increased incidence of ischemic heart disease and circulatory disorders

Radiation Hormesis and Space Exploration

Extended human space-exploration requires an in-depth understanding of LDIR effects. Life on Earth has evolved with fluctuating background radiation (currently ~2.4 mSv/year), with evidence suggesting LDIR promotes cellular repair, immune function, and metabolic efficiency via hormetic mechanisms [1, 2]. Evidence indicates exposure below this baseline impairs physiological function, while modest increases in LDIR enhance biological responses [5, 6, 7, 8]. Therefore, maintaining a base LDIR level appears critical for optimal health. For long-duration space travel, replicating Earth's LDIR may be essential to preserve astronaut health [3, 4]

Conclusion

The debate on radiation hormesis and the necessity of LDIR for life remains unresolved despite decades of research. However, studies suggest that biological health declines below Earth's natural background radiation, implying LDIR may be essential for life. Therefore, for long-term space travel, spacecraft may need to regulate radiation exposure to mimic Earth's LDIR. Given the conflicting data, further investigation is crucial, with research looking into potential optimal exposure thresholds for space exploration.

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