Commentary

The Pros and Cons of Using Earth's High Background Radiation Areas as an Analog for Mars Colonization: A Critical Analysis

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ABSTRACT

The establishment of a Martian colony is one of the most significant technological challenges currently facing humanity. The journey and the Martian environment present numerous obstacles, making this mission extremely complex. However, extensive research is underway to investigate the viability of a Mars expedition and settlement. If humans are to stay on Mars for an extended period, they will need to overcome several challenges, including the high levels of space radiationand microgravity. Even if all necessities for human colonization on Mars are provided, high levels of ionizing radiation remain a critical issue. This study aims to address the potential risks and long-term effects of radiation exposure in challenging environments like Mars by reviewing the health effects of individuals on Earth who live under similar conditions and experience comparable radiation exposure. Specifically, it highlights the crucial importance of the studies on the health effects of individuals who currently live or migrate to high background radiation areas like Ramsar, Iran, where residents of certain hot spots can receive up to 260 mSv per year, primarily due to the decay chain of radium-226. By acknowledging both the pros and cons of using Earth's high background radiation areas as an Analog for Mars colonization, and by employing a multifaceted approach, scientists can gain valuable insights to prepare for the challenges of human habitation on Mars.

Keywords

Adaptive Response; High Dose Background; Low Dose Background; Mars Colonization; Interplanetary Health Risks; Mars; Radiation Effects; Space Flight

Introduction

Over the past several years, the senior scientists of our research center have actively been involved in studies on the health effects of living in areas with extremely elevated levels of natural background radiation such as in Ramsar, Iran as one of the few places on Earth with high background radiation areas (HBRAs) [1-22]. The primary culprit behind Ramsar's high radiation is the natural decay of radioactive elements in the soil and rocks. These elements, like Ra-226, release ionizing radiation as they break down over time. Ra-226 is a specific decay product in the radioactive series of U-238, which is particularly abundant in Ramsar's geology. This element emits alpha particles, a high LET ionizing radiation. Exposure to high levels of ionizing radiation can have various health risks, although the exact effects in Ramsar are still under investigation.

Research suggests residents of HBRAs like Ramsar might have developed some level of adaptation to the radiation over generations. This adaptation could potentially offer some protection against health effects. However, studies on the health effects of Ramsar's population are ongoing, and data might be limited due to factors like sample size and long-term health tracking challenges. Existing research primarily focuses on the health of native residents who have adapted over time [14]. The effects on newcomers, which might be more relevant for Mars colonists, are less understood.

Given these considerations, Ramsar's HBRAs provide a valuable opportunity to study the effects of chronic, low-dose radiation exposure on human health. This knowledge can inform preparations for potential health risks faced by future Mars colonists. However, limitations exist, and Mars presents a different radiation environment with additional stressors. Further research and a multifaceted approach are crucial for ensuring the safety of future space endeavors.

The Health Concerns

The health concerns related to natural radiation in Ramsar include cancer risk, genetic mutations, and cardiovascular and other health effects. Human exposure to high levels of radiation exposure can be associated with an increased risk of developing cancer, particularly leukemia and solid tumors. High levels of radiation exposure can lead to genetic mutations that may be inherited by future generations. Some studies suggest that high levels of radiation exposure may also increase the risk of cardiovascular disease, cataracts, and other effects [23,24].

Despite the unique opportunity to study the long-term effects of radiation exposure on human health, there is still much we do not understand about the mechanisms by which radiation causes health effects. Given these considerations, the health concerns related to natural radiation in Ramsar underscore the need for ongoing research and understanding of the long-term effects of radiation exposure on human health. The insights gained from studying natural radiation in Ramsar may also inform the management of radiation exposure in other contexts, such as in the workplace or following nuclear accidents.

As Welsh et al. [6] noted, conducting experiments on lab animals exposed to low-LET radiation may be quick, easy, and inexpensive, but it does not provide much insight into the actual radiobiological risks of future manned space missions. To create a more accurate model, humans could be exposed to high-LET radiation similar to that found in space. In certain regions of the world, such as Ramsar, Iran, people have been exposed to both low and high-LET background radiation for thousands of years. Studying the health of individuals in these areas may provide valuable information applicable to space missions.

Ramsar as a Biological Model for Ramsar

Abbasi et al. [25] previously noted that residents in high background radiation areas (HBRAs) of Ramsar receive an annual dose of radiation that is 10 times higher than the limit recommended by the ICRP. In some regions, residents receive radiation doses as high as 260 mSv, which is 13 times higher than the occupational dose limit recommended by the ICRP. A report in Popular Science suggests that the background radiation in Ramsar, Iran, is similar to that on Mars. However, the maximum annual radiation dose in high background radiation areas (HBRAs) of Ramsar can be significantly higher than that on Mars. Talesh Mahalleh, a district in Ramsar, is reported to have the world's highest levels of natural radioactivity. According to C Net, the best candidates for Mars colonists may come from places like Iran and Brazil [2] Despite these concerns, most residents continue to live in their homes without any reported adverse effects. However, due to the small sample size, it is not possible to conclusively determine the health effects of high-level natural radiation in Ramsar, particularly regarding cancer risk. More studies are needed to provide further information [2].

Potential Cognitive and Behavioral Impairments

As Mortazavi et al. [12] noted, radiation exposure in space affects astronauts differently than radiation exposure on Earth, raising concerns about potential cognitive and behavioral impairments due to exposure of their central nervous system. This raises the possibility of developing dementia and other motor neuron diseases. NASA is interested in studying radium deposition in the human brain and the effects of exposure to high linear energy transfer (LET) alpha particles, which mimic the exposure astronauts may experience during future Mars missions. However, it is important to note that alpha particles tend to accumulate in the bone and have a very short range, so the radiation dose would be localized near the cranium. A study conducted on individuals with high levels of radium ingestion in areas with high background radiation showed that exposure to high LET particles did not affect working memory but did increase reaction times [26]. Further research is needed to determine if these findings are relevant for deep space missions.

Ionizing radiation, originating from the sun and other celestial sources, poses a significant threat to humans on Earth and other planets, such as Mars. On Mars, the thin atmosphere and weak magnetic field allow these ionizing rays to easily penetrate the planet's surface, potentially endangering human inhabitants. The radiation dose on Mars' surface can vary, but it typically is much higher than the dose deemed safe for humans on Earth. While Mars' thin atmosphere and weak magnetosphere expose it to high cosmic radiation levels (around 240 millisieverts per year), some places on Earth actually have even higher background radiation. Ramsar, Iran, holds the record for the highest annual radiation dose from natural sources, with some areas reaching a staggering 260 millisieverts per year (Figure 1).

Various tests have been conducted to investigate the potential harm to native residents of high background radiation zones, with mixed

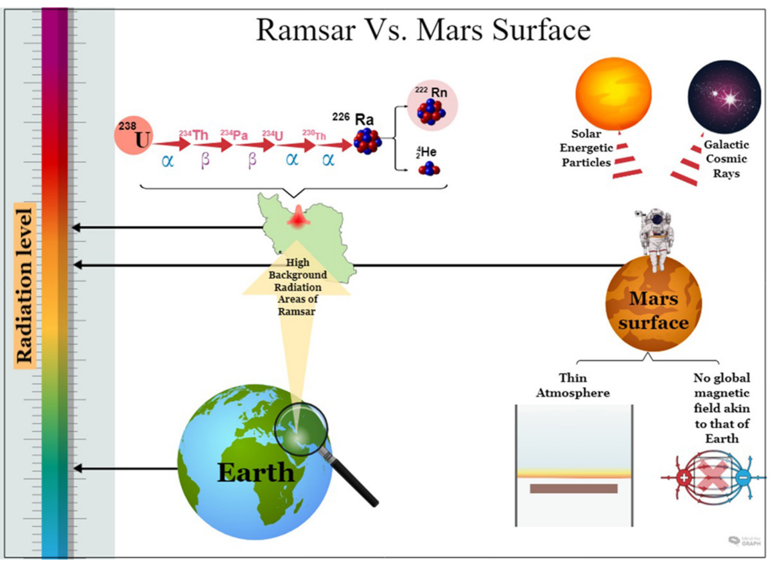

Figure 1: Comparison of the annual radiation dose in Ramsar, Iran, with that of the Martian surface.

results regarding health effects. However, the adaptive response of individuals' cells to high radiation exposure in the face of a challenging dose is intriguing. Laboratory studies have reported lower chromosomal abnormalities in people living in high background radiation areas compared to those outside these regions [14].

Lack of Data Regarding the Individuals Who Migrate to Ramsar

Considering the adaptive response that confers radiation resistance to native residents in high background radiation areas, the implications for non-native individuals who migrate to these regions become a matter of interest. Studying the adaptive responses and health outcomes of immigrants to high background radiation areas can provide valuable insights into the potential adaptation and health trajectories of future Mars inhabitants. While there are differences in radiation sources and environments between Earth and Mars, both groups will be transitioning into a relatively similar environment with different challenge doses, highlighting the potential comparability between these two scenarios in terms of individuals adapting to a new radiation environment.

While there are constraints in comparing the impacts of radiation on Earth and Mars, examining the commonalities and distinctions between these two groups can enhance our comprehension of potential risks, adaptive strategies, and enduring effects of radiation exposure in demanding environments. It's crucial to exercise caution when making comparisons between the effects of radiation on Earth and Mars due to differences in radiation sources, intensities, and protective factors. However, investigating the adaptive responses and health outcomes of individuals residing in high background radiation areas on Earth can offer valuable insights into the possible adaptation and health paths of future Mars settlers.

Pros and Cons of Using HBRAs as an Analog for Mars Colonization

By acknowledging both the pros and cons of Using HBRAs as an Analog for Mars Colonization, and by employing a multifaceted approach, scientists can gain valuable insights to prepare for the challenges of human habitation on Mars. Table 1 summarized the most important pros and cons.

In this context, HBRAs offer a valuable starting point for studying the effects of radiation on human health, but limitations exist. While research on HBRAs can inform Mars colonization efforts, it shouldn't be the sole source of information. Efforts to recreate Martian radiation environments in labs or through particle accelerators can provide more targeted data on potential health risks. It is worth noting that Mars presents a combination of stressors beyond radiation, including microgravity, low atmospheric pressure, and a harsh chemical environment. So, studying the combined effects of these factors is crucial. Moreover, any research on human populations in HBRAs requires careful ethical considerations to ensure informed consent and minimize any potential risks to participants.

Conclusion

In conclusion, while Earth's high background radiation areas (HBRAs) like Ramsar offer valuable insights into radiation adaptation, they have limited comparability to Martian conditions due to differences in radiation types and environmental stressors. HBRA studies can provide a starting point, but Mars-specific research with particle accelerators and simulations is essential. A comprehensive, multifaceted approach is needed to address the combined challenges of radiation, microgravity, and the unique Martian environment for safe human colonization.

Authors' Contribution

SAR. Mortazavi contributed to the conceptualization of the study and manuscript

Table 1: Pros and cons of using high background radiation areas (HBRAs) as an analog for Mars colonization

Pros	Cons
• Radiation Exposure HBRAs like Ramsar, Iran, offer a unique opportunity to study the effects of chronic low-dose radiation exposure on human health. This information can be valuable for understanding the potential health risks faced by Mars colonists exposed to Martian radiation.	**• Limited Comparability** Radiation on Mars is different from Earth’s background radiation. It’s primarily high-energy particles like protons and heavy ions, while Earth’s HBRAs involve exposure to gamma rays and alpha particles. This difference might limit the direct applicability of findings from HBRAs.
• Adaptive Response Research suggests that individuals living in HBRAs might have developed some level of adaptation to radiation exposure. Studying these potential adaptations could offer insights into how future Mars inhabitants might adjust to their new environment.	**• Focus on Native Populations** Most research focuses on the health effects on native residents of HBRAs who have adapted over generations. The effects on non-native individuals migrating to these areas, which might be more relevant to Mars colonists, are less understood.
• Accessibility Studying human populations in HBRAs is far more feasible and cost-effective compared to conducting research missions on Mars.	**• Data Limitations** Existing data on the health of HBRA populations might be limited, with challenges in sample size and long-term health tracking.

HBRAs: High Background Radiation Areas

drafting. SMJ. Mortazavi provided expertise in radiation biology, guided the study’s framework, and contributed to the critical review and revision of the manuscript. H. Vafapour conducted the literature review, organized data on HBRAs, and assisted in manuscript writing. All authors reviewed and approved the final version of the manuscript.

Conflict of Interest

SMJ. Mortazavi, as the Editorial Board Member, was not involved in this manuscript’s peer-review and decision-making processes.

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