Radiation

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Natural **Radiation** on Mars is much higher compared with Earth. The thin atmosphere provides only a small shielding effect against cosmic radiation. It provides moderate protection against solar radiation. Mars also lacks the magnetosphere that protects Earth.

The average natural radiation level on Mars is 24-30 rads or 240-300 mSv per year(needs checking and reference). This is about 40-50 times the average on Earth.

1 millisievert [mSv] = 0.1 rad [rd]

Contents

Types of Radiation

Radiation comes in a variety of forms:[1]

Name	Relative Biological Effectiveness (RBE)	Source
X-Rays and Gamma Rays	1	Radiation belts, solar radiation, and bremsstrahlung electrons
Electrons 1.0 MeV 0.1 MeV	 1 1.08	Radiation belts

Protons 100 MeV 1.5 MeV 0.1 MeV	 1-2 8.5 10	Cosmic radiation, inner-radiation belts, and solar radiation
Neutrons 0.05 ev (thermal) 1.0 MeV 10 MeV	 2.8 10.5 6.4	Nuclear interactions in the sun; on Mars, produced when cosmic radiation interacts with regolith
Alpha Particles 5.0 MeV 1.0 MeV	 15 20	Cosmic radiation, Cosmic rays
Heavy Ions	Varies widely	Cosmic radiation
Table 1: Types of radiation		

(RBE is a measure of the damage done to living tissue, relative to gamma rays)

Cosmic radiation comprises 85% protons, 14% alpha particles, and 1% heavy ions.[2] Solar radiation includes the same radiation types, but it a higher proportion of protons and its heavy primaries have lower energy levels. The high-energy heavy primaries in cosmic radiation can penetrate materials that effectively block lower-energy radiation[3].

Exposure limits

Limits for humans

Exposure to dangerous levels of radiation causes radiation sickness and cancer. Any exposure to radiation, no matter how slight, poses some risk. Small dose - small risk of cancer. High dose - high risk of cancer. The average exposure to radiation on Earth due to natural sources is 6.2 mSv per year[4]. The highest natural exposure is recorded in Ramsar, Iran, where people are exposed up to 260 mSv/y since many generation, with no reported harmfull effect[5]. It should be emphasized, that low level radiation doses spread over a long period of time (long enough that the bodies natural functions have time to repair the damage), are far less dangerous than large doses received in a short amount of time. (In fact numerous studies show health benefits from extremely low levels of radiation.) See: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6149023/. https://www.sciencedaily.com/releases/2017/09/170913104428.htm. https://www.ajronline.org/doi/full/10.2214/ajr.179.5.1791137. https://en.wikipedia.org/wiki/Radiation_hormesis

Nevertheless, there are defined legal limits for exposure during work for several professional activities, such as for X-ray assistants, airplane personnel, etc. The International Commission on Radiation Protection recommends that occupational (work-related) radiation exposure be limited to 50 millisieverts (mSv) per year, and limited to 100 mSv over any 5-year period[6]. NASA's radiation dose limits for astronauts are established in NASA-STD-3001[7].

There is scientific uncertainty surrounding the health hazard from cosmic and solar radiation, because most past research on the health effects of radiation studied only x-rays and gamma rays[3].

Limits for plants

"In general, plants are relatively radiation resistant when growing and extremely resistant as dormant seeds." Radiation would not interfere with raising plants as food sources, at least not on the time scales of exploration missions.[8]

Table 2 shows the limits for plants(source of table required, in space or on mars?). It shows that in practically all cases plants can survive radiations events that are likely for Mars without any kind of protection.

ORGANISM	OBSERVABLE EFFECTS	LETHAL DOSE
Human (Annual limit < 0.05 Sv)	~0.25 Sv	~4.50 Sv
Onion	~3.77 Sv	~14.91 Sv
Wheat	~10.17 Sv	~40.22 Sv
Corn	~10.61 Sv	~41.97 Sv
Potato	~31.87 Sv	~126.08 Sv
Rice	~49.74 Sv	~196.77 Sv
Kidney Beans	~91.37 Sv	~361.49 Sv
Potential Dose: Solar Maximum: ~0.40 Sv Solar Maximum: ~1.20 Sv Solar Flare: ~5.00 Sv		

Table 2: Need to find source for this table

Martian Environment

Effects of the Martian atmosphere

Most SPE particles will be stopped by the atmosphere before they reach the surface. However, interactions with atmospheric particles can produce neutrons; those neutrons can reach the surface, so the health hazard is not eliminated.

Cosmic radiation protons are likely to penetrate the atmosphere. Cosmic ray heavy ions may fragment in the atmosphere, producing lower-mass ions that can still harm astronauts on the surface.

Mars' thin atmosphere allows more ultraviolet light to reach the surface, compared to Earth. However, habitat structural materials and standard space suits should be sufficient to protect humans from UV radiation.[9]

Mars atmosphere effect depends on the considered inclination, as the incoming radiations will cross more matter if it's coming from the horizon rather than from the zenith. For inclination angles greater than ~45°, the atmospheric thickness is in the range from 20-30 g/cm2, and for lower inclination angles, the atmospherie thickness can exceed 100 g/cm2[10].

Low gravity effects on atmospheric thickness

Note that the radiation protection given by the Martian atmosphere is higher than would be expected considering the air pressure. Pressure can be thought of the weight of the air above you in the atmosphere. Mars' gravity is 38% of Earths. So the weight of that air is less than it would be on Earth. On other words, more air must be above you on Mars to give the same pressure, compared to Earth. For example, you might think that since Mars' air pressure is 0.6% of Earth's, the radiation protection would also be 0.6%. However, the mass of air above you on Mars is 1/38% or 2.6 times thicker than that pressure on Earth. If we were to terraform Mars to have 10% Earth's pressure, the radiation protection by that atmosphere would be 26%. If we were to give Mars an atmosphere of 50% Earth's air pressure, then the Martian atmosphere's radiation protection would be 132% that of Earth.

Effects of regolith

When cosmic radiation strikes regolith, it can cause the impacted atoms to emit their own radiation. Surrounding regolith particles absorb much of this radiation, with the exception of neutrons.

Neutrons generated in this way are called albedo neutrons. These neutrons have the potential to add substantially to the radiation dose for astronauts on the surface.[9]

Dose received by an unprotected human on Mars

Cosmic radiation

The equivalent dose rate from cosmic radiation on Earth's surface at sea level is 0.26 mSv per year[4]. Based on measurements made by the Curiosity rover, the corresponding figure for the surface of Mars is approximately 230 mSv/year[11]. More generally, one model estimated that the dose equivalent rate on the surface of Mars ranges from 156.4 mSv/year (at solar maximum) to 273.8 mSv/year (at solar minimum)[10][12]. A 2005 report by the Mars Human Precursor Science Steering Group estimated that (at solar minimum) the dose from cosmic radiation would be 1.2 +/- 0.5 mSv/day; this includes 0.4 +/- 0.4 mSv/day from albedo neutrons.[9]

Solar Proton Events

Curiosity also measured the temporary increase in radiation during a single SPE. The results indicate an increase in equivalent dose rate of approximately 25% over a 1-day interval[11]. This figure will vary depending on the intensity of a particular SPE.

Effect on material

Radiation can change the properties of plastics and metals, making them brittle after a period of time.

Protection

Long term habitats should be equipped with a radiation shielding, thick enough to reduce the radiation to a level equal to Earth, that is, almost zero. Best protection may be achieved with houses built in natural caves or set into cliffs or hillsides.

Early exploration habitats could have water tanks, or sand bags above where people live. When radiation goes thru water, every 18 cm reduces the radiation by half. So a water tank 108 cm thick (6 halvings) will reduce the radiation level by 64 times. (As a bonus, water is a good neutron absorber.) Packed soil has a halving-distance of 9.1 cm, so 55 cm of hard soil would provide a similar level of protection. In general, it is far better to use local materials for radiation protection, rather than hauling them from Earth. See: https://www.imagesco.com/geiger/lead-shielding-guide.html.

Space suits must be designed with radiation in mind. The suit should provide adequate shielding for the occupant. It may be necessary to design suits with several grades of protection. Suits designed for short-term use can carry lighter shielding which would reduce weight and improve maneuverability.

During severe radiation events, such as solar flares, surface settlements may use storm shelters with heavier than normal shielding.

"In this work, it is shown that on the Martian surface, almost any amount of aluminum shielding increases exposure levels for humans. The increased exposure levels are attributed to neutron production in the shield and Martian regolith as well as the electromagnetic cascade induced in the Martian atmosphere. This result is significant for optimization of vehicle and shield designs intended for the surface of Mars." [10]

"An in-situ shielding strategy will also be of little help unless several hundred g/cm2 of regolith is utilized. Such a strategy would probably require large scale excavation making it an unlikely candidate. Instead, the shielding strategy would rely primarily on material optimization. Options, such as replacing aluminum structures with high hydrogen content carbon composites, could be pursued." [10] This opinion is open to argument as in-situ resources utilization for any type of settlement should make large amounts of regolith available for construction. It mainly is true for the very first level of habitats.

The use of g/cm2 can be translated into an equivalent thickness that depends on the material density. For martian regolith at 2000 kg/m3, a thickness of 1m of regolith is 200 g/cm2. Water (or ice) is 100 g/cm2. So the minimum covering for a long term settlement would be 5m or more. For water, although the radiation absorption is better the density is lower, so about the same thickness would be required for protection (to be discussed)

References

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External links

- IPS: (http://www.ips.gov.au/) A Guide to Space Radiation (http://www.ips.gov.au/Category/Educational/Space%20Weather/Space%20Weather%20Effects/guide-to-space-radiation.pdf)
- Nuclear Industry Association: Radiation, health and nuclear safety (http://www.niauk.org/radiation-and-safety.html)
- The frequency distribution of solar proton events: 5 solar cycles and 45 solar cycles (https://hesperia.gsfc.nasa.gov/sspvse/posters/DF_Smart/poster.pdf)
- Low levels of radiation can be stimulatory: Radiation Hormesis

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