Radiation dose and protection by a lunar hole and lava tube

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The lunar surface is directly exposed to high energetic particles such as Galactic Cosmic Ray (GCR) particles and Solar Energetic Particles (SEPs), which are shielded by thick atmosphere and geomagnetic field on the Earth. Long term manned missions to the Moon, Mars or deep space will occur more severe radiation exposure than that we have experienced, which may result serious health hazards of space crews. Then, strategic radiation protection is mandatory to guarantee health of crews by relieving radiation dose.

The Moon is the closest celestial body to the Earth and expected as a next body developed by humans in near future. Recently, cameras on SELENE have discovered vertical holes on the lunar surface, at Marius Hills, Mare Tranquillitatis and Mare Ingenii. It is considered that such lunar vertical holes are formed by meteorite impacts collapsing the roof on lava tubes. Therefore, entrances of lava tubes may open at the bottom of the vertical holes. Radar observation suggests a possible lava tube exists about 100m in depth at a subsurface near a vertical hole at Marius Hills. Vertical holes associating lava tubes reduce radiation dose of cosmic ray particles coming from the zenith. In this work, the radiation dose at the lunar surface was numerically evaluated, and its reduction in the lunar vertical hole was estimated. The GCR particles in solar minimum and maximum phases and large SEP events, called ground level enhancement (GLE) events observed on the Earth, are assumed as primary events.

The effective dose equivalent due to GCR particles reached up to 267.8 mSv/y in solar minimum phase, and that due to a GLE event observed at Jul. 2000 was 509 mSv/event at the lunar surface. It was found that the contribution of secondary particles to the total radiation dose was ~8% at most. This fact implies that the elemental composition of lunar surface, whether mare region or highland region for example, does not make any considerable difference in the total radiation dose. On the other hand, the radiation dose become ~10% at the center bottom of vertical hole expecting Marius Hills, 50 m in diameter and 43 m in depth. The radiation dose reduction is mainly due to the solid angle of primary particle. However, the contribution of secondary particles increased to ~20% at the bottom. This is also due to the solid angle subtended by the secondary particle sources, the wall and bottom of the hole. The effective dose equivalent reduced to 20 mSv/y at the edge bottom of the vertical hole. This value corresponds to the reference value of occupational exposure determined by ICRP. If there is over 25 m space, 50 m from the hole center, the effective dose equivalent becomes less than 1.0 mSv/y, the reference value of public exposure. Our results show that the vertical hole and lava tubes are promising sites for human long stay in future from the aspect of radiation protection. The detail results of numerical experiments and evaluation of space radiation protection will be presented and discussed.

Keywords: Radiation dose, Lunar holes, Radiation protection