STERILIZATION OF MARTIAN SAMPLES BY GAMMA IRRADIATION

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The question of sterilizing extraterrestrial material prior to its introduction into the biosphere will certainly be raised when the first samples are collected on Mars. A recent poll of nearly one hundred scientists concerned with planetary geology and biology revealed almost unanimous opposition to traditional sterilization methods based on dry heating or steam[1]. Among the objections were possible changes to gases and liquids, the destruction of delicate alteration phases and structural damage to clay minerals. A number of the respondents suggested that, if sterilization was performed at all, irradiation would be preferable to heating.

Ionizing radiation is currently used to preserve or sterilize food in a number of countries. Radiation is also widely used in the United States to sterilize medical instruments[2]. The most common source is gamma radiation from cobalt-60. Complete sterilization of food is achieved with an absorbed dose of approximately 10^6 rad (1 rad = 0.01 joule/kg).

The effects of a radiation dose of this magnitude must be well understood before it can be seriously proposed as a sterilization technique for Martian samples. A number of relevant experiments have been reported by researchers in the nuclear waste disposal community. These include studies of the effects of irradiation on rock forming minerals, clay minerals, salt, and water. This research was conducted to assess the response of proposed repository and barrier materials to the gamma flux in the vicinity of nuclear waste containers.

Rock Forming Minerals Spitsyn et al.[3] subjected feldspars and quartz to varying doses of cobalt-60 gamma radiation and examined the samples with optical and electron microscopy, x-ray diffraction and infrared spectrometry. They reported color changes in the feldspars, micron-scale surface coatings, minor loss of crystallinity and shifts in some of the spectral peaks. These effects were initiated at absorbed dosed of 10^7-10^8 rad.

Clay Minerals Krumhansl[4] exposed smectite (sodium montmorillonite from bentonite) to cobalt-60 gamma doses of 3×10^{10} rad. X-ray diffraction data indicated no significant changes. Heat capacity measurements showed the loss of interlayer water to be the only crystallographic effect of irradiation. The irradiated samples did liberate significant amounts of carbon dioxide and hydrogen, and consumed essentially all of the oxygen present in the system.

Allen and Rawson[5] studied smectite which had been exposed to 3.5×10^9 rad of cobalt-60 gamma radiation over two weeks and at the same time heated to 300°C. The treated samples and starting materials were examined by x-ray diffraction and transmission electron microscopy. The only observed change was reversible loss of interlayer water. High resolution images of the clay's basal lattice structure showed no evidence of damage at the molecular level.

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Spitsyn et al.[3] used x-ray diffraction to characterize smectite, nontronite, kaolinite and chlorite subjected to gamma doses ranging from 10^7 - 10^9 rad. They reported no structural changes in the clays other than partial dehydration.

Salt Pederson[6] described results from gamma irradiation of natural rock salts and synthetic NaCl at doses of 10^8 - 10^9 rad and temperatures of 50° and 150°C. At the lower temperature the salts turned dark blue in color, indicating the formation of sodium colloids. Salts from the higher temperature experiments became light brown, a color typical of anion vacancies containing a trapped electron (F-centers). Heating of the samples to 190°C caused the recombination of radiation-induced defects.

Jockwer and Monig[7] studied the gases released by irradiated samples of rock salt. They reported significant levels of CO_2 and CO, produced by desorption, and N_2O from radiolysis of air. In addition, trace levels of H_2S, SO_2 and Cl_2 were measured.

Water Jantzen and Bibler[8] noted that radiolysis of pure water forms equal amounts of oxidizing (H_2O_2, OH) and reducing (H_2, H) species, which rapidly recombine. If H_2 escapes, the remaining liquid will become oxidizing.

These authors also studied groundwater in equilibrium with basalt. In this system the gamma irradiated water became more reducing, as a consequence of the partial dissolution of iron-rich basalt mesostasis glass.

Gray and Simonson[9] measured the gases produced by gamma irradiation of rock salt brines at 75° and 150°C. The total doses ranged as high as $2x10^{10}$ rad. The gases consisted of H_2 and O_2 in an approximate ratio of 2:1.

If sterilization of Martian rock and soil is deemed necessary, gamma irradiation should certainly be considered as an alternative to heat or steam. Doses on the order of 10^6 rad, sufficient to kill living organisms, are essentially benign to silicate minerals. Further research is required to assess the effects of such a dose on water, ice and the Martian atmosphere.

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