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Naturally Induced Secondary Radiation in Interplanetary Space: Preliminary Analyses for Gamma Radiation and Radioisotope Production from Thermal Neutron Activation

by

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Thermal neutron activation analyses were carried out for various space systems components to determine gamma radiation dose rates and food radiation contamination levels. The space systems components selected were those for which previous radiation studies existed. These include: manned space vehicle radiation shielding, lunar habitat regolith shielding, liquid hydrogen propellant tanks for a Mars mission, and food supply used as space vehicle radiation shielding.

The computational method used is based on the fast neutron distribution generated by the BRYNTRN and HZETRN transport codes for GCR at solar minimum conditions and intense solar flares in space systems components. Fast neutrons slow down to thermal energies and their transport is assumed to be described satisfactorily by thermal neutron diffusion theory. Thermal neutron losses due to capture in (n, γ), (n,α) and (n,p) reactions is accounted for in a set of neutron activation differential equations which describes the formation of the radioactive isotopes. In shielding analysis only the (n,γ) reaction is considered, and prompt as well as delayed gamma rays are included in the volumetric radiation sources.

The gamma dose rates for soft tissue are calculated for water and aluminum space vehicle slab shields considering volumetric source self-attenuation and exponential buildup factors. In the case of the lunar habitat with regolith shielding a completely exposed spherical habitat was assumed for mathematical convenience and conservative calculations. Table I summarizes the gamma dose rates for the various space systems analyzed, and for comparison purposes the GCR and solar flares dose rates for the same components are given. Note that the gamma dose rates in all cases is not very significant.

Activation analysis of food supply used as radiation shielding is presented for four selected nutrients: potassium, calcium, sodium, and phosphorus. Radioactive isotopes that could represent a health hazard if ingested are identified and their concentrations determined. The results are presented in Tables II and III. For nutrients soluble in water it was found that all induced radioactivity was below the accepted maximum permissible concentrations.

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Table I. Preliminary Results of Gamma Dose Rates Calculations Versus GCR or Solar Flares Dose Rates

Space System Component	Gamma dose Rates	GCR or Solar Flares Dose Rates
<u>Manned Space Vehicle Shielding</u>		
• GCR: aluminum slab (18.5 cms)	18.54 mrem/yr	30.9 rem/yr
• GCR: water slab (50 cms)	2.64 mrem/yr	22.9 rem/yr
• Solar flares: aluminum slab (18.5 cms)	7.60 mrem for 1 day	~ 10 rem for 1 day
<u>Lunar Spherical Habitat Shielding</u>		
• GCR: Lunar regolith (50 cms)	< 1 rem/yr	12 rem/yr
<u>Liquid Hydrogen Tank</u>		
• GCR: cylinder (r = 5.5 m, = 21.1 m)	< 0.2 for a 500 day mission	(27.8 - 36.7) rem for 500 day mission

Table II. Concentration of Radioisotropes from Thermal Neutron* Activation of Food Nutrients

Nutrient	Isotope	Relative Concentration**		Saturation Time	Half-life
		1 Year Period	Saturation Time		
Potassium (K^{39},K^{40},K^{41})	K^{42}	10^{-60}	10^{-19}	∞	12.36 hr
	Cl^{36}	10^{-35}	10^{-12}	∞	3×10^{5} yr
	Cl^{38}	$<< 10^{-35}$	10^{-22}	∞	37.2 min
Calcium (Ca^{40}, Ca^{42},Ca^{43}, Ca^{44},Ca^{46})	Ca^{45}	10^{-88}	10^{-27}	∞	165 days
	Ca^{47}	10^{-123}	10^{-42}	∞	4.5 days
Sodium (Na^{23})	Na^{24}	10^{-20}	10^{-20}	150 hr	15 hr
Phosphorous (P^{31})	P^{32}	10^{-18}	10^{-18}	140 days	14 days

*10^{8} neutrons/cm^{2}-yr

**atoms/atoms of nutrient, order of magnitude given

Table III. Concentration of Radioisotropes from Thermal Neutron Activation of Food Nutrients Versus Maximum Permissible Concentrations (MPC) Values

Nutrient	Isotope	Concentration (1 year period) (μC_i/gm of nutrient)	Fluid milk (nonfat) (μC_i/gm of H_2O)	MPC* (μC_i/gm of H_2O)
Sodium	N_a^{24}	10^{-7}	1.26×10^{-9}	10^{-6}
Phosphorus	p^{32}	10^{-7}	2.47×10^{-8}	5×10^{-4}

* Occupational exposure; for nutrients soluble in water