Comments and Suggestions for Space Radiation Research

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Research indicates that the impact of radiation on human tissue is dominated by high LET.

Figure 1 shows that the radiation cross section increases with LET, especially for the LET value from 10 to 100 keV/μm. The risk contributed by high LET (≥10 keV/μm) is ~ 140 times that contributed by low LET (≤10 keV/μm).

Risk cross section + LET spectra measured => Risk

CR-39 is the ideal detector for measuring LET spectra for astronauts, when used correctly.

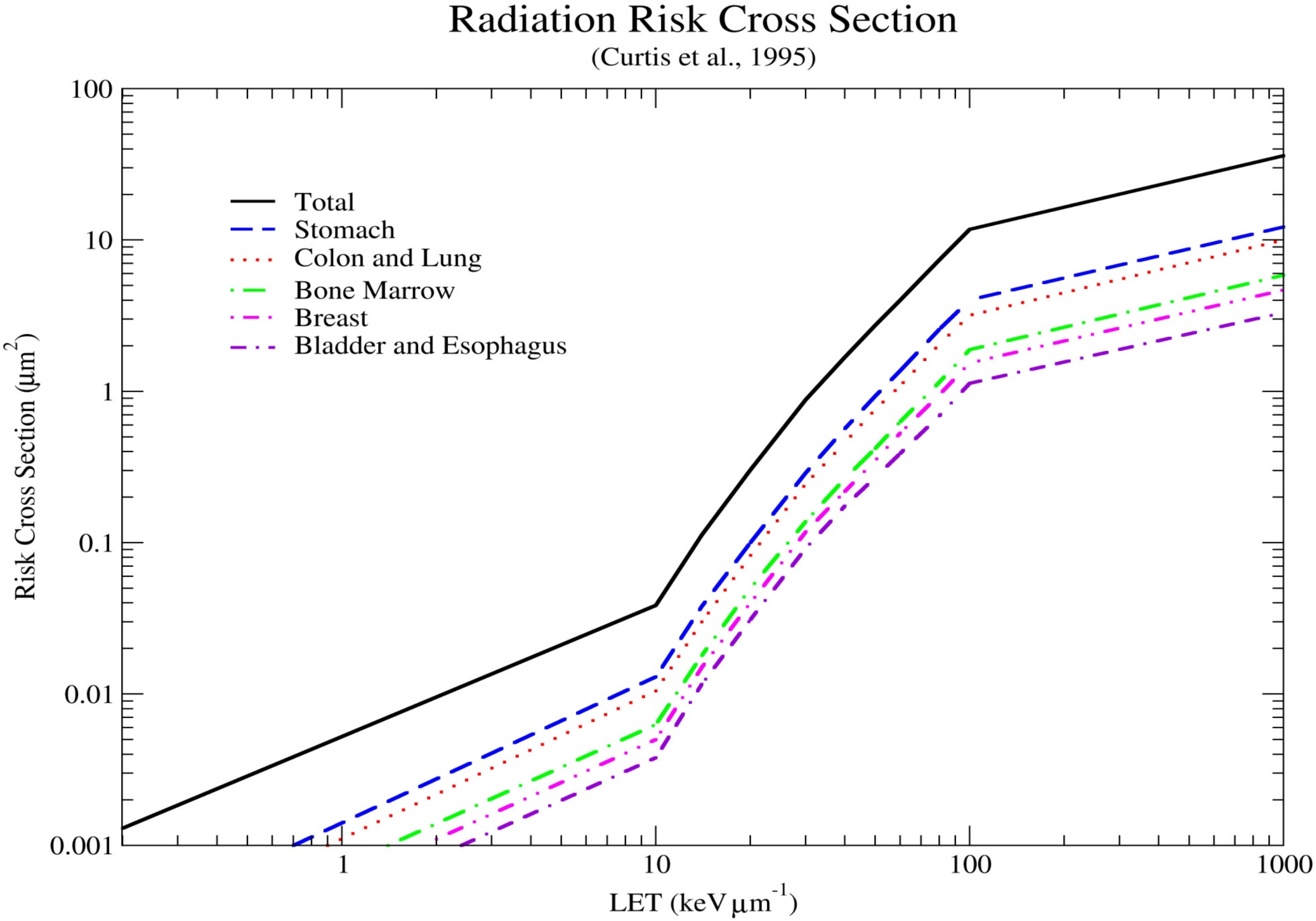

Fig.1: Risk cross section determined by radiobiology [1]

Research Methods

The purpose of the space radiation research for astronauts is to measure the radiation quantities and to estimate the radiation risk resulting from space radiation.

There are two approaches

experiment and simulation.

Except for the sleeping time, **astronauts are always in a moving state inside or outside the space vehicle**, so the shielding / instruments / equipment / structure environment around the astronauts is changing and the change can not be recorded or tracked accurately.

1) Simulation Method

Simulation method uses computer codes to simulate the physical procedures and to calculate the radiation quantities and the radiation risk for astronauts.

Advantages: flexibility to obtain radiation estimates for organs and for locations beyond LEO.

Disadvantages:

a) cannot track motion of astronaut and the change of his environment;

b) interaction cross section for Z = 1-26 and E > 0.1 GeV/n in human tissue (C, H, O) is so,far not fully known .

c) No standard approach to energy loss formulae.

2) Experimental Methods

TLDs/OSLDs + CR-39 PNTDs => Radiation Quantities

Risk Cross Section + LET Spectrum => Radiation Risk

Advantages: No problems on:

Astronaut tracking;

Interaction Cross Section;

Energy Loss Calculation.

Disadvantages:

Difficult to obtain organ dose and dose equivalent.

However Matroshka work can help to some degree.

Combination of Simulation and Experimental Methods

a) **Improve codes using experimental data;**

b) **Use both methods for same astronaut and space mission;**

c) **Compare results and determine the scaling factor if necessary.**

The Case for CR-39 Method

In addition to the radiation quantities and LET spectra in LEO, CR-39 detectors also provide accurate LET spectra on background radiation.

Main issues:

a) **Etching:** Chemical etch only to save LET information;

b) **Scanning:** manual/semiautomatic scan

c) **Correction for sensitivity fading** of CR-39 with long term exposures

d) **LET calibration methods thorough.**

Table 1: Comparison of chemical etch and electric-chemical etch for CR-39

	Chemical Etch	Electric-Chemical Etch
LET information	Yes	No
LET spectrum	Yes	No
Usable for risk estimation	Yes	No
Particle Number	Yes, as a function of LET and different event contributes different dose	Only number and every event has same contribution to dose
Combination with low LET dose (TLDs, OSLDs)	Yes, the combination can give total dose and dose equivalent for all LET	No

Table 2: A comparison of different scan methods [2]

	Manual Scan and Semi-automatic scan	Fully Automatic Scan
Ability to distinguish real events (space + background) and unreal (etched spots from material defects)	Yes	No
Ability to distinguish the overlapped events and read them correctly	Yes	No
Ability to obtain HZE particles in the same procedure of data scan for all events	Yes	No
Data scanned reliable?	Yes	No

Table 3: Radiation measured without (^) and with fading (*) correction for CR-39 sensitivity (values include background) [3,4]

Mission (Time)	Exposure Position	Absorbed Dose (≥10keV/µm water)	Dose Equi. (ICRP60) (≥ 10 keV/µm water)	Q Factor
(Days)		(mGy)	(mSv)	
Matroshka-1 (616)	P1	29.90^/ 36.94*	270.97^/ 437.00*	9.06^/ 11.83*
	Eye	14.94 / 21.60	176.59 / 274.82	11.82 / 12.72
	Stomach	14.96 / 18.89	156.95 / 246.13	10.49 / 13.03
	R1	13.90 / 17.93	148.74 / 217.31	10.70 / 12.12
	R2	13.85 / 17.55	135.29 / 215.04	9.77 / 12.25
Matroshka-2 (367)	P1	10.86 / 12.90	121.10 / 150.66	11.15 / 11.68
	Eye	9.13 / 10.99	106.88 / 134.48	11.71 / 12.24
	Stomach	8.40 / 9.66	96.23 / 118.82	11.46 / 12.30
	R2	11.23 / 12.97	123.85 / 152.16	11.03 / 11.73
Expedition 12 (190)	TEPC	5.31 / 6.19	60.06 / 69.03	11.32 / 11.15
	TESS	4.92 / 6.22	59.21 / 68.89	12.04 / 11.08
	SMP327	5.31 / 6.83	68.98 / 78.48	12.98 / 11.49
	SMP442	7.99 / 10.59	89.05 / 105.61	11.14 / 9.97
Expedition 13 (183)	TEPC	4.90 / 6.23	65.33 / 74.20	13.33 / 11.91
	TESS	4.55 / 6.18	64.09 / 73.39	14.09 / 11.88
	SMP442	7.98 / 9.31	94.90 / 109.95	11.89 / 11.81

New Generation Active Personal Dosimeter TEPSC

(Tissue Equivalent Plastic Scintillator Counter)

Developer: RMD (Radiation Monitoring Devices, Inc., Boston) [5]

TEPSC => Plastic Scintillator + SSPM (Solid-State Photomultiplier)
(several cm^2) (several cm^2)
Integrated into CHIP

Why plastic scintillator, not silicon (Table 4)?

a) PS are sensitive to both charged particles and neutrons;
b) A key fundamental work – light response of PS to relativistic nuclei (Z = 1-26, E > 0.1 GeV/n) was obtained by University of Chicago in 1980s using BTV (Birks-Tarle-Voltz) core-halo model [6].

Table 4: Radiation around the 80 cm concrete shielding [7]

(1 PIC = 2.2×10^4 particles impinging on the target)

	Absorbed Dose	Dose Equivalent (ICRP 60)	Q Factor
	(nGy/PIC)	(nSv/PIC)	
RRMD-III without acrylic plate	0.073	0.107	1.46
RRMD-III with acrylic plate	0.081	0.117	1.44
DOSTEL	0.068	0.137	2.01
HANDY TEPC		0.265	
NASA TEPC		0.280	5.48

Possible Reasons:

1. CERF is a neutron reference field, silicon are not sensitive to neutrons but TEPCs are;
2. Different response functions for the different dosimeters;
3. Conversion factor from LET in silicon to LET in water is ~ 1.2, too small.

References

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