Results from recent ground based (HIMAC) and space (ISS) exposures using TL and OSL dosimeters

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Introduction

- Dose equivalent:

$$H = \sum_i H_i = \sum_i D_i \times Q_i$$

- NCRP 142, 2002 Recommendation 11:

$$H = QD_{OSLD/TLD} + \int Q(L)\, D_{PNTD}(L)\, dL$$

LET ≤ 10 keV/μm; Q = 1

LET ≥ 10 keV/μm; Q = Q(L)

Evaluate the potential of OSL from Al_2O_3:C for dose determinations in low-LET region

Experimental details

Material: Luxel™ (Al_2O_3:C powder in polycarbonate film); Al_2O_3:C chips

HIMAC irradiations (ICCHIBAN 4)

- 'Known-ion' exposures: ^{4}He, ^{12}C, ^{20}Ne, ^{28}Si, ^{56}Fe; energies of 600 MeV – 2.8 GeV; doses of 1, 10, 50 and 100 mGy
- 'Unknown-ion' exposures: single and mixed field ions

Space Irradiations

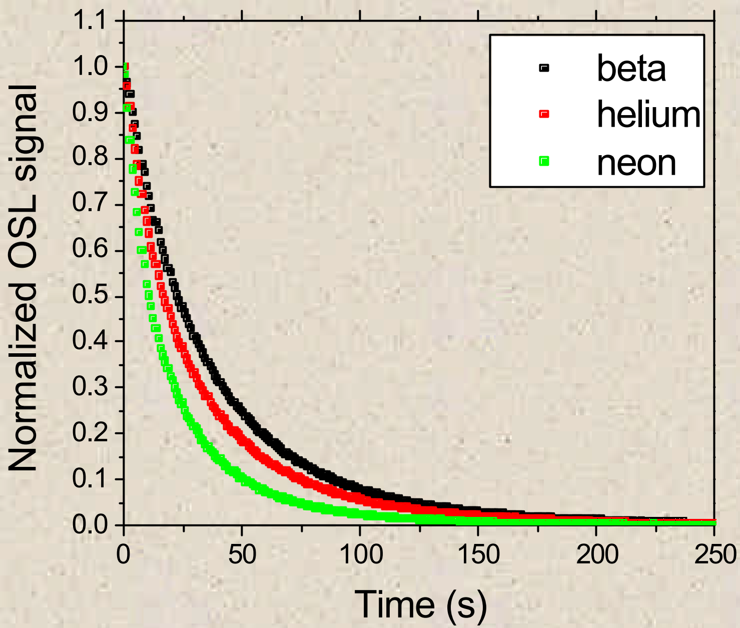
- MESSAGE 2 (10 days) and MOBILIZATION (11 days) & BRADOS (91.5 days)

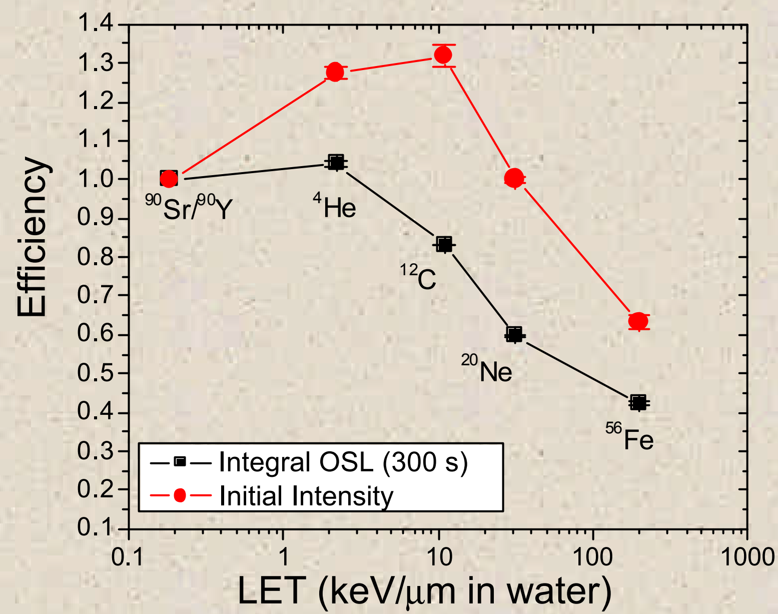
OSL measurements

- The experiments were performed in CW-OSL mode using a Risø TL/OSL-DA-15 reader
- Stimulating light: green diodes (525nm), U-340 filters
- OSL signal: Integral OSL (300 s) and Initial Intensity (3 s)

Known radiation fields: Efficiency vs LET

- We measure "equivalent" gamma dose $D_?$ from the OSL signal
- Absorbed dose is obtained by correcting $D_?$ by efficiency ?





$$D = \frac{D_g}{h}$$

$$h = \frac{S_{HCP}/D_{HCP}}{S_R/D_R}$$

Unknown mixed radiation fields

- Absorbed dose $$D = \sum_i D_i = \sum_i \frac{D_{g,i}}{h_i}$$

- But we measure $$D_g = \sum_i D_{g,i} = \sum_i h_i D_i$$

Question:

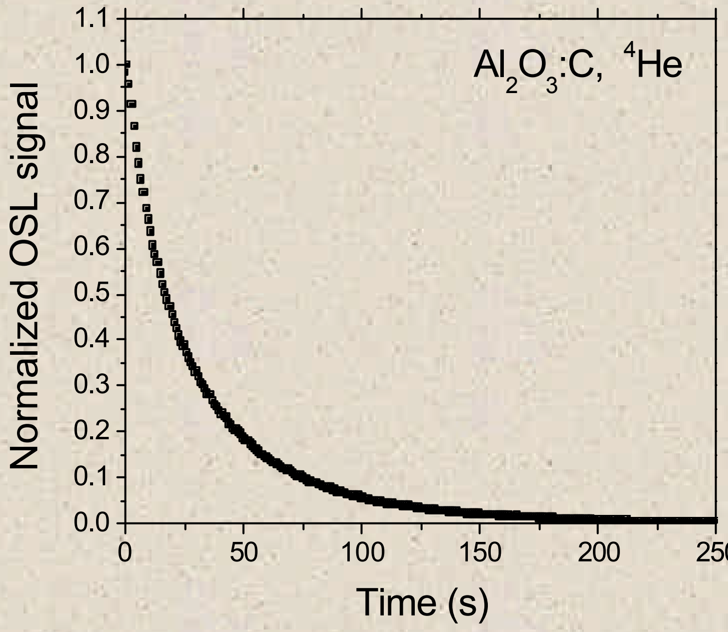
- Can we calculate a 'mean' efficiency, such that: $$D = \frac{D_g}{h_{mean}}$$?

To calculate a "mean" efficiency:

What parameters of the OSL decay curve depend on LET ?

(1) R- Ratio:

$$R = \frac{D_g(area)}{D_g(I_0)}$$

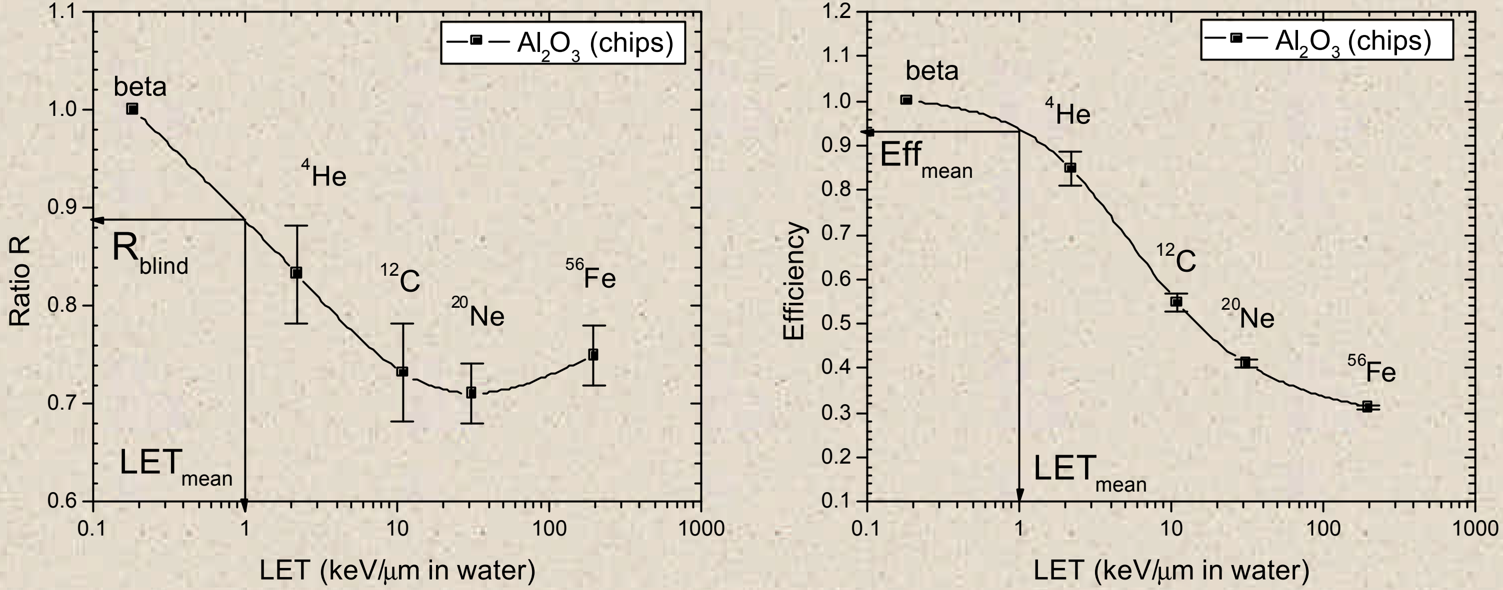


(2) t -Ratio:

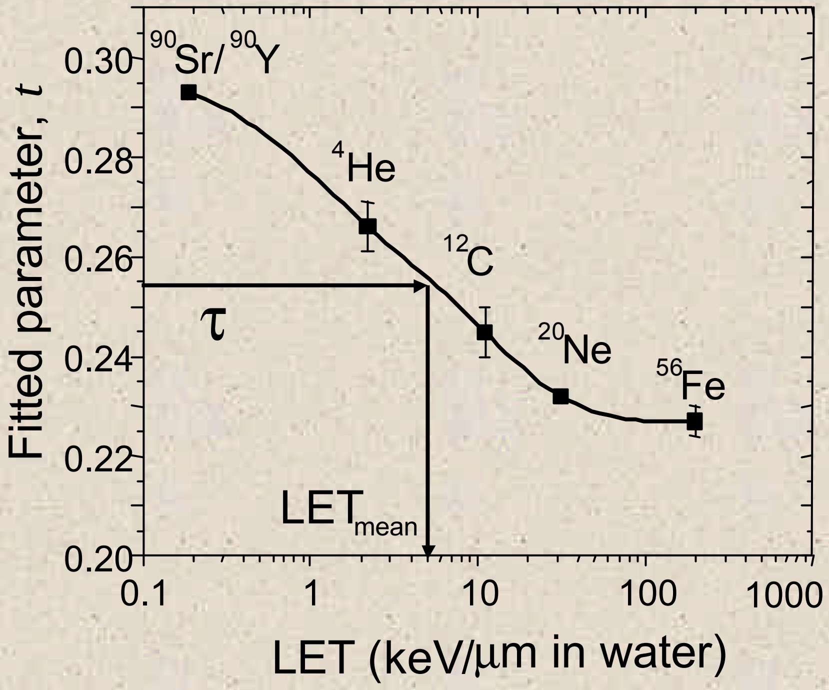
$$I_{OSL} = \sum_k A_k \exp\left(-\frac{t}{t_k}\right)$$

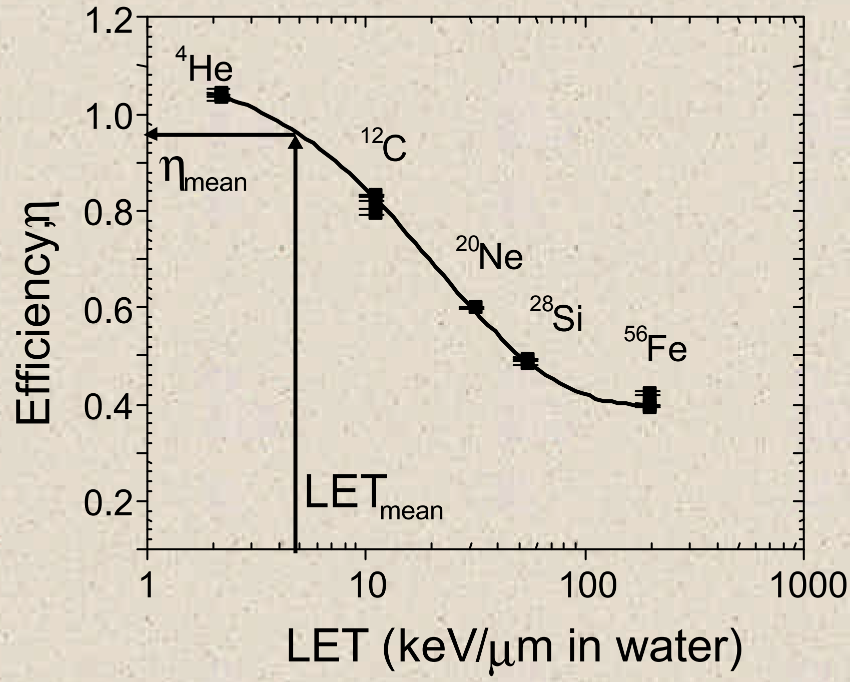
Ratio of t_1 by t_2 from an exponential fit of the OSL decay curves $t = t_1 / t_2$

Estimation of the 'mean' efficiency' by R- ratio method



Estimation of the 'mean' efficiency' by *t* - ratio method





'mean' LET → 'mean' efficiency → absorbed dose (?)

'mean' LET → 'mean' Q → dose equivalent (?)

Results I: Absorbed dose

'Unknown-ion' exposure	Measured dose (mGy)	Integral OSL (mGy) R-method	Integral OSL (mGy) t – method	Actual dose (mGy)
Unknown #1	31.0 ± 0.2	29.2 ± 0.3	28.5 ± 0.3	27.8
Unknown #2	26.2 ± 0.0	26.0 ± 0.1	25.3 ± 0.4	25.0
Unknown #3	13.4 ± 0.0	12.6 ± 0.1	12.5 ± 0.2	12.6
Unknown #4	8.4 ± 0.1	8.7 ± 0.3	11.2 ± 1.0	10.2
Unknown #8	20.8 ± 0.2	24.8 ± 0.7	25.4 ± 1.3	25.0

Example results from ICCHIBAN 4

(doses to water, using "blind" identities revealed by Benton)

Results II: Dose equivalent

'Unknown-ion' exposure	Dose equivalent H (Sv)	Corrected dose equivalent t– method
Unknown #1	27.8	28.5 ± 0.3
Unknown #2	25.0	25.3 ± 0.4
Unknown #3	20.4	12.5 ± 0.2
Unknown #4	64.9	35.7 ± 1.0
Unknown #8	33.0	25.4 ± 1.3

Results III: MESSAGE & MOBILIZATION

Multiple TLD/OSLD types: Example data

	ISS –7 (containers) Dose rate (μGy/d)
Al_2O_3:C (OSL)	162 ± 3
Al_2O_3:C (OSL)	165 ± 2
^{7}LiF:Mg,Ti (TL)	194 ± 17
^{7}LiF:Mg,Cu,P (TL)	154 ± 4
^{7}LiF:Mg,Cu,P (TL)	154 ± 12
Al_2O_3:C (TL)	178 ± 14

^{7}LiF:Mg,Ti (TL) > Al_2O_3:C (TL) > Al_2O_3:C (OSL) > ^{7}LiF:Mg,Cu,P (TL)

Results III: MESSAGE & MOBILIZATION (cont.)

Efficiencies

LET [keV/µm] Nom. Value	^{7}LiF:Mg,Cu,P	^{7}LiF:Mg,Ti	Al_2O_3:C (OSLD)	Al_2O_3:C (TLD)
2.26	0.78	1.12	0.83	0.89
10.8	0.51	0.92	0.53	0.56
55.5	0.32	0.55	0.33	0.37
189	0.29	0.45	0.3	0.32

Same ordering:

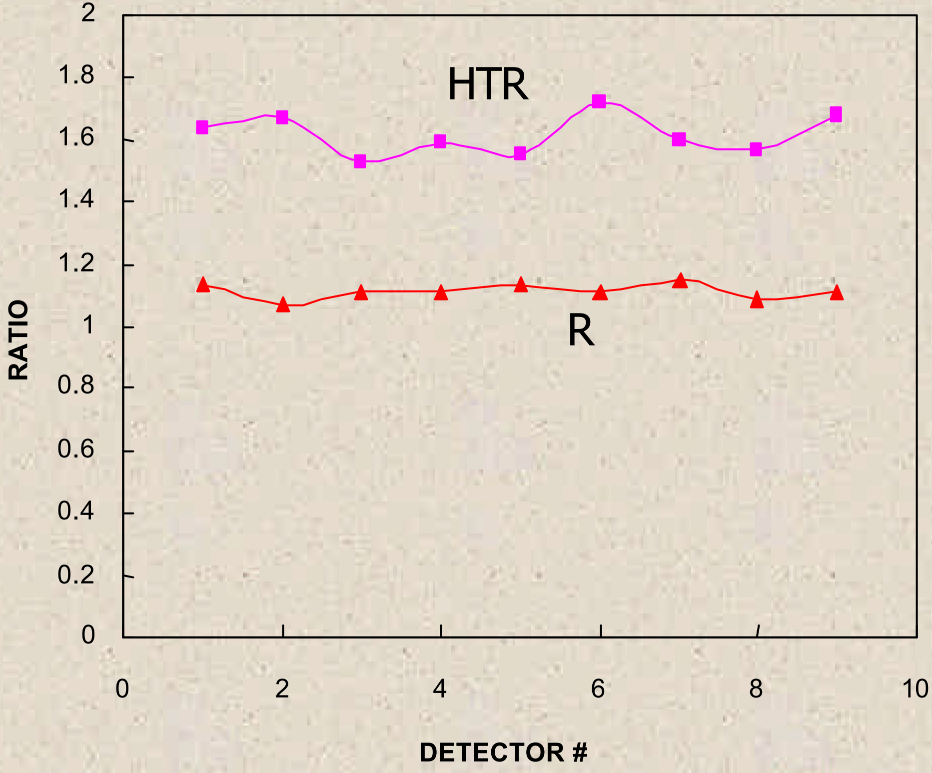
^{7}LiF:Mg,Ti (TL) > Al_2O_3:C (TL) > Al_2O_3:C (OSL) > ^{7}LiF:Mg,Cu,P (TL)

PNTD data show that >95% of the OSL/TL signal from low-LET

Results IV: BRADOS

	TLD- 500	
#	Area	I_o
1	16.8	19.1
2	16.2	17.3
3	16.0	17.8
4	15.0	16.7
5	16.8	19.1
6	15.1	16.8
7	15.2	17.5
8	14.5	15.7
9	14.3	15.9

(in mGy)



Results IV: BRADOS (cont.)

Al_2O_3:C - OSL

Layer (detector #)	'Corrected' dose (mGy) *R*-method
#1	18.6 ± 1.0
#2	16.6 ± 1.4
#3	17.0 ± 2.8
#4	15.9 ± 4.9
#5	18.5 ± 1.7
#6	16.1 ± 0.4
#7	17.0 ± 1.0
#8	14.9 ± 0.7
#9	15.2 ± 1.9

Weighted average LET = 0.8 ± 0.1

LiF:Mg,Ti - TL

Layer (detector #)	'Corrected' dose (mGy) *HTR*-method
#1	22.7 ± 0.5
#2	22.2 ± 0.6
#3	22.3 ± 0.4
#4	20.7 ± 0.5
#5	21.0 ± 0.9
#6	20.5 ± 0.9
#7	19.9 ± 1.1
#8	19.9 ± 0.1
#9	19.8 ± 0.4

Weighted average LET = 2.5 ± 0.1

Conclusions

- OSL (and TL) measure primarily the low-LET component.

- Differences in evaluated doses are primarily due to differences in low-LET efficiencies, rather than high-LET efficiencies.

- The OSL signal from Al_2O_3:C using both R-Ratio method and t -Ratio method can be used with good accuracy to estimate the absorbed dose for: (a) unknown low-LET single radiation fields, and (b) unknown mixed radiation fields with a strong low-LET component and a weak high-LET component.

- For increased high-LET contribution to the incident radiation field, the errors in estimating both the absorbed dose and (especially) dose equivalent increase.

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