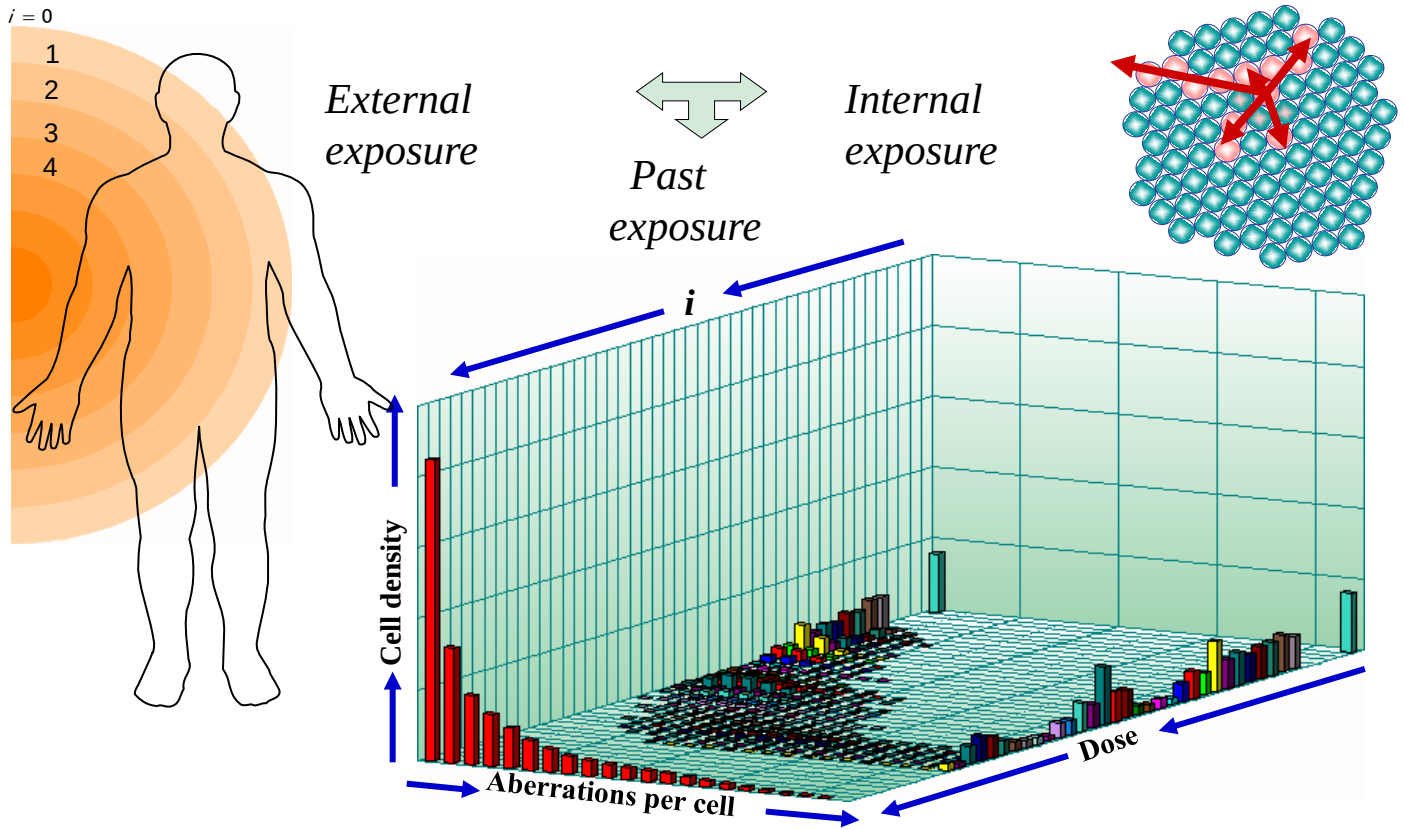
A Generalized Biodosimetry System for Human Radiation Exposure

In human radiation exposure, the dose distribution is usually non-uniform, due to dose attenuation (external exposure), non-random hit by decay of radionuclide (internal exposure), or dilution of the exposed cells by tissue recovery (past exposure). The method has been developed to estimate the dose components in non-uniform distribution of radiation dose by unfolding chromosome aberration distribution into a dose distribution profile (M. S. Sasaki, *Int. J. Radiat. Biol.*, 79:83-97, 2003).

The rationale of the method is that the observed frequencies of cells with r aberrations is a mixture of subpopulations each having a specific mean frequency, m_i, which is defined by specific dose, D_i.



The overall aberration frequency, $f(r)$, of cells with r aberrations should follow a mixed Poisson distribution as expressed by

$$f(r) = \sum_{i=1}^{n} \phi(m_i)(e^{-m_i} m_i^{\,r}) / r! \qquad G = \frac{2}{x^2}[x - 1 + \exp(-x)], \quad and \quad x = T / T_0,$$

where $m_i = f(D_i)$ is a mean aberration yield as a function of dose, D, and is expressed by:

$$f(D) = (C + \alpha D + \beta G D^2)\exp(-\xi D) + n[1 - \exp\{-\frac{1}{\xi}(\gamma D + \delta G D^2)(1 - \exp(-\xi D))\}] + \varepsilon$$

G is G-function of Lea for protracted (chronic) exposure, in which T is time (hours) of dose protraction and T_0 is the mean life time of chromosome breaks (G=1 hour for acute exposure).

The observed distribution of chromosome aberrations is fitted by iteratively re-weighted maximum likelihood method combined with the bootstrap resampling as shown in the following.

$$s^2 = \sum_{i=0}^{r} w_i [v_{i,j}(r) - n_i(r)]^2 = \min$$

Iteration (i)

Bootstrap (j)

j=0,1,2,3, , , , , , , ,BTN. (BTN=number of bootstrap resampling). w_i is weight, which is in an inverse function of variance. Bootstrap samples, $v_j(r)$, are obtained by randomized redistribution of residual as are formulated by,

$$v_j(r) = v(r) + \varepsilon^*, where\ \varepsilon^* \ni \varepsilon_0, \varepsilon_1, \varepsilon_2, \varepsilon_3, , , ,$$

The dose distribution profiles thus obtained may be adjusted by lymphocyte survival, $S = D/D_0$. Any D_0 values may be used, but D_0=3 Gy in literature is recommended (Edwards et al., Int. J. Radiat. Biol., 38:83-91, 1980). The equivalent whole body dose (EWBD), exposed fraction (F_X) and the dose to the exposed fraction (D_X) are given, respectively.

$$EWBD = \sum_{i=1}^{k} \phi(m_i) D_i, \qquad F_X = \sum_{i=1}^{k} \phi(m_i), \qquad D_X = \frac{1}{F_X} \sum_{i=1}^{k} \phi(m_i) D_i$$

Dose assessment: Examples

Reference dose-response parameters
(human G_0 lymphocytes for γ-rays *in vitro*)

Dic: dicentric. cR: centric ring. aR: acentric ring.

Parameters	Dic+cR+aR		Dic		Dic+cR	
(C±SE)	8.50E-04	1.85E-04	6.47E-04	1.62E-04	8.50E-04	1.85E-04
(α±SE)/Gy	2.31E-02	9.31E-02	1.83E-02	9.95E-03	2.32E-02	4.73E-03
(β±SE)/Gy^2	6.41E-02	3.70E-03	5.43E-02	3.95E-03	6.15E-02	3.43E-03
(γ±SE)/Gy	1.29E-05	4.38E-06	1.23E-05	4.21E-06	1.26E-05	5.39E-06
(δ±SE)/Gy^2	3.44E-07	1.00E-07	3.69E-07	9.89E-08	3.96E-07	1.51E-07
(ξ±SE)	1.00E-01	1.54E-02	1.02E-01	1.40E-02	1.01E-01	1.91E-02
n	18		14		15	

A: Mixture of equal volume of whole blood, each irradiated with 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5 and 5 Gy γ-rays in vitro. Total dose is equivalent to 2.75 Gy. The mixed blood was kept at 37°C for 24 hrs under aeration of 5% CO_2 before commencement of culture. **B**: Victim of Goiania accident. **C**: Victim of Chernobyl accident. Dose profiles either (**1**) unadjusted or (**2**) adjusted by lymphocyte survival with D_0=3 Gy. EWBD: equivalent whole body dose (Gy). Fx: exposed fraction. Dx: dose (Gy) to the exposed fraction.