The Response of Alanine Detectors in Thermal and Epithermal Neutron Fields

T.Schmitz[1], N. Bassler[2], M. Blaickner[3], M. Ziegner[3,4], Y.H. Liu[5], I. Auterinen[6], H. Palmans[7], P. Sharpe[7], P. Langguth[8], G. Hampel[1]

[1]Institute for Nuclear Chemistry, University of Mainz, Mainz, Germany, [2]Department of Exp. Clinical Oncology, Aarhus University Hospital, Aarhus, Denmark, [3]AIT Austrian Institute of Technology GmbH, Vienna, Austria, [4]Vienna University of Technology, Vienna, Austria, [5]Nuclear Science and Technology Development Center, National Tsing Hua University, Taiwan, ROC, [6]VTT Technical Research Centre of Finland, Finland, [7]National Physical Laboratory, Teddington, Middlesex, UK, [8]Department of Pharmacy and Toxicology, University of Mainz, Mainz, Germany

Introduction: Alanine detectors are known especially for dosimetry in photon fields. In this work their response towards neutron fields of different energies has been investigated. Neutron fields always consist of secondary particles generated in nuclear processes. For the alanine detector three dose components have been identified:

- Gamma dose (D_g): Deposited by gammas generated by thermal neutrons in (n,γ)-reactions in the detector, but also with structure materials.
- Proton dose (D_p): Deposited by protons generated with a kinetic energy of 560 keV after thermal neutron capture by the nitrogen isotope ^{14}N.
- Fast neutron dose (D_n): Deposited by recoiling protons from elastic scattering of fast neutrons on hydrogen. On average the proton energy is half of the energy of the incident neutron.

Dose components are analogue to those in tissue, due to similar element composition of alanine and tissue. Most relevant difference is the about five times higher nitrogen content in the alanine detector.

Experimental setup: Detectors have been used in comparable PMMA phantoms in the thermal neutron field of the thermal column of the research reactor TRIGA Mainz and in the epithermal fields of the BNCT facilities at the research reactors FiR1 in Helsinki, Finland, and THOR in Hsinchu, Taiwan.

Alanine pellets have been manufactured and read out at the primary standard laboratory at the National Physical Laboratory (NPL), United Kingdom [1]. The alanine pellets were made of 90 % microcrystalline alanine and 10 % paraffin wax. Irradiated with ionizing radiation, alanine forms the stable radical CH3–ĊH–COOH. Using an electron spin resonance (ESR) spectrometer, the unpaired electron at the carbon atom can be detected. Using calibration by ^{60}Co-photons a dose response value $R_{Alanine}$ can be assigned to each ESR signal.

Relative Effectiveness (RE): The concept of RE values is used according to formula (1) to transform $R_{Alanine}$ into physical dose $D_{Alanine}$. Considering the dose components mentioned above $R_{Alanine}$ can be calculated according to formula (2). Values of RE_i and D_i have been calculated using the Hansen & Olsen Model [2] together with the Monte Carlo Code FLUKA [3].

$$RE = R_{Alanine}/D_{Alanine} \quad (1)$$

$$R_{Alanine} = RE_g D_g + RE_p D_p + RE_n D_n \quad (2)$$

Since photons have been used for calibration RE_g is unity. Due to the low range of nitrogen protons they are stopping in the detector. Therefore RE_p has been found to be constant at 0.56. Recoiling protons of D_n are of higher energies and therefore not necessarily stopping in the detector. In addition the proton energy is a function of the neutron energy, which is depending on neutron field and detector position. Varying values between 0.58 and 0.70 have been found.

Results: Measured dose responses could be reproduced by calculations for all pellets. In figure 1 $R_{Alanine}$ is shown as a function of depth on the longitudinal axis in the PMMA phantoms at the TRIGA Mainz and at FiR1Helsinki representing an epithermal neutron field. The dose rate is normalised to the maximum of each curve. This maximum corresponds to 1.7 Gy/min at the TRIGA and 0.16 Gy/min at FiR1. The biggest difference is the build-up effect in epithermal fields reaching a maximum at 2 cm depth, while no such effect has been observed in the thermal neutron field.

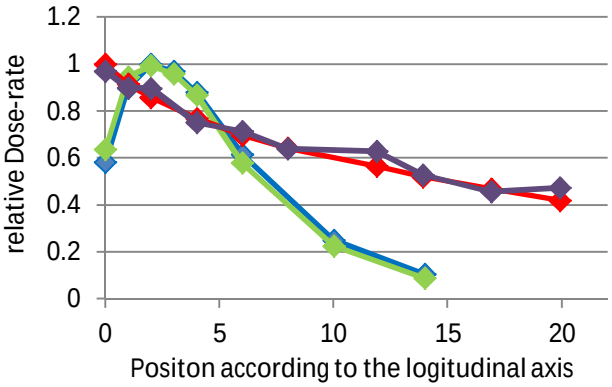

Figure 1: Dose response $R_{Alanine}$ on the longitudinal axis of the phantoms (measured: blue – FiR1, red –TRIGA; calculated: green – FiR1, purple – TRIGA)

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