INVESTIGATION OF RADICAL FORMATION AND OXYGEN DEPLETION IN FLASH AND CONVENTIONAL RADIOTHERAPY USING EPR SPIN TRAPPING

Johanna Pehlivan[1], Elke Beyreuther[2], Felix Horst[2], Oliver Jäkel[3] , Axel Klix[1], Dieter Leichtle[1], Jörg Pawelke[2] , Bernhard Holzapfel[4]

[1]Karlsruhe Institute of Technology (KIT), Institute for Neutron Physics and Reactor Technology, Eggenstein-Leopoldshafen, Germany; [2]OncoRay – National Center for Radiation Research in Oncology, Faculty of Medicine And University Hospital Carl Gustav Carus, Technische Universität Dresden; Helmholtz-Zentrum Dresden – Rossendorf (HZDR), Dresden, Germany; [3]Deutsches Krebsforschungszentrum (DKFZ), Heidelberg, Germany; [4]Karlsruhe Institute of Technology (KIT), Institute for Technical Physics (ITEP), Eggenstein-Leopoldshafen, Germany

Background & Objective:

Hypothesis: UHDR water radiolysis generates concentrated radicals → altering radical dynamics → reducing DNA-damaging radicals.

Experiment:

- Irradiation of water samples with varying O_2 concentrations.
- Continuous monitoring of O_2 concentrations during irradiation.
- Post-irradiation radical concentrations analyzed using electron paramagnetic resonance (EPR) spin trapping.

Objective: Investigate the effect of UHDR on O_2 depletion and radical generation.

Methods:

- **Irradiation** at ELBE@HZDR accelerator (30 MeV electrons) with $\dot{D}$: 0.12 Gy/s, 300 Gy/s, 8.5×10^4 Gy/s.
- **Water samples** prepared with PBS (pH 7.4), DTPA and DMPO spin trap at different O_2 concentrations.
- **EPR** spectra recorded ~4 minutes post-irradiation with Bruker Magnettech ESR5000
- **Oxygen concentration** monitored using OXR50-UHS fiber-optic sensor (PyroScience)
- **Dosimetry** performed with FlashDiamond (PTW) and EBT-XD film (Gafchromic)

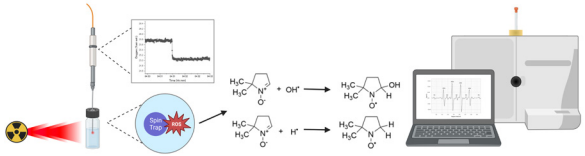

Figure 1: Schematic of the measurement process: irradiation, real-time O_2 measurement and post-irradiation spin-trapping spectrum measurement.

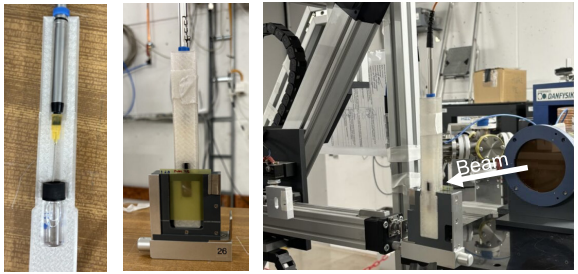

Figure 2: Experimental setup: Sample with oxygen sensor, dosimetry configuration using film dosimeter and complete setup at the accelerator.

Results:

- Dose rate dependence of O_2 depletion.
- Dependence on initial O_2 levels.
- Dependence on spin trap (scavenging of H•).
- EPR spin trapping method successfully captured HO• and H• produced through radiolysis.
- EPR data showed increased radical concentration at FLASH dose rates

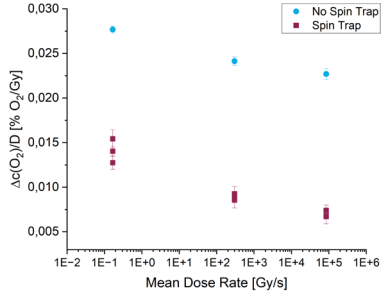

Figure 3: O_2 depletion as a function of dose rate, samples with ~1% initial O_2 concentration.

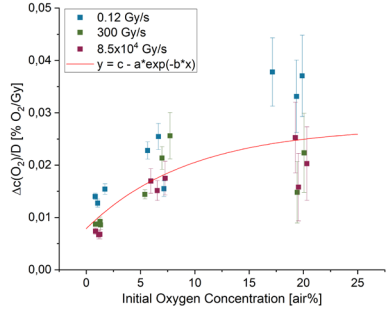

Figure 4: O_2 depletion as a function of initial O_2 concentration.

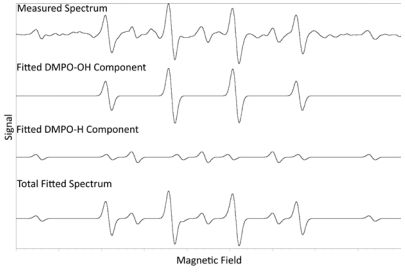

Figure 5: EPR spectrum of samples with DMPO and fitted spectrum for DMPO-OH and DMPO-H.

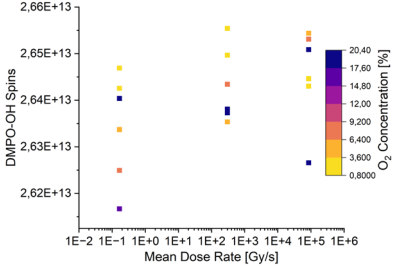

Figure 6: DMPO-OH spins as a function of mean dose rate.

Conclusion: Our findings on O_2 depletion are in agreement with previously published data [1], [2]. This study demonstrates the proof of concept for detecting and quantifying radiation-induced radical formation at a wide range of dose rates.

Contact: johanna.pehlivan@kit.edu
KIT – The Research University in the Helmholtz Association

References: **[1] Jansen et al. (2022)**, Radiother. Oncol., 175, 193–196, doi: 10.1016/j.radonc.2022.08.024. **[2] Sunnerberg et al. (2024)** , *Int. J. Radiat. Oncol.*, S0360301624035107, doi: 10.1016/j.ijrobp.2024.10.018.
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