This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 662287.

EJP-CONCERT

European Joint Programme for the Integration of Radiation Protection Research

H2020 – 662287

D 9.122 - Irradiation and dosimetry procedures

Lead Author: ENEA

Reviewer(s): Soile Tapio, Munira Kadhim, Fiona Lyng and CONCERT coordination team

Work package / Task	**WP 9 (Task 9.7 SEPARATE)**	**SST 9.7.1.1 Irradiation and dosimetry procedures**
Deliverable nature:	**Report**	
Dissemination level: (Confidentiality)	**Public**	
Contractual delivery date:	**Month 34**	
Actual delivery date:	**Month 34**	
Version:	**1**	
Total number of pages:	**6**	
Keywords:		
Approved by the coordinator:	**Month 34**	
Submitted to EC by the coordinator:	**Month 34**	

Abstract

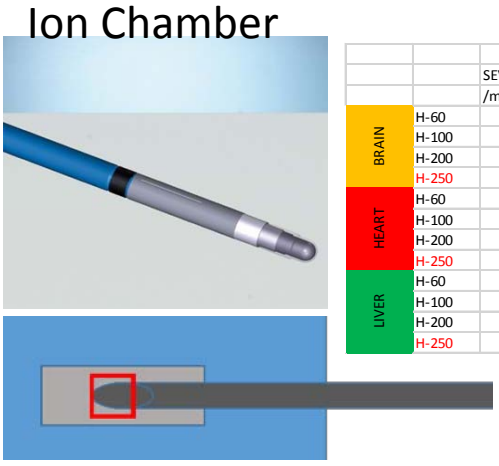
Work performed within Sub-subtask 9.7.1.1 was focused on the dosimetric evaluation in the Irradiation set up for shielded irradiation of mice within the SEPARATE programme. Two independent dosimetric methods have been successfully implemented and tested. Conclusions with both methods were that, under the foreseen experimental conditions, there is no significant dose to the shielded organs. Further work during the ongoing SST9.7.1.1 is expected to provide additional input through Monte Carlo simulation.

Sub-subtask 9.7.1.1 - Dosimetry

Dosimetry was carried out for mice irradiated at postnatal day 80 with 0.1, 0.25, and 2Gy of x-rays, with individual lead parallelepipeds used to protect the anterior two-thirds of the body, with the hindmost part directly exposed to radiation. Irradiation was delivered with a Gilardoni CHF 320 G X-ray generator operated at 60, 100, 250 kVp, 15 mA, with HVL = 1.6 mm Cu (additional filtration of 2.0 mm Al and 0.5 mm Cu). To insure conditions of extended phantom and full backscatter, irradiation was performed on a perspex rectangular solid phantom (length, width: 40 cm; height: 10 cm). At irradiation distance of 67.7 cm, the absorbed dose rate at the center of the irradiated volume in muscle was 1.03 Gy min-1 with relative expanded uncertainty of 10%, confidence level 95%.

Dose monitoring was made using a PTW 7862 large-size plane parallel transmission chamber connected to a PTW IQ4 electrometer. The absorbed dose delivered at a given depth in an extended muscle phantom was determined from the measured value of the air kerma on the basis of the “in-air method” (1), and using the function "Percentage Depth Dose" (2). Dose measurements were carried out by a cylindrical NE 2571 ionization chamber, coupled to a Farmer 2570/1 electrometer, calibrated in terms of Air Kerma at the Italian National Metrological Institute (3).

Experimental measurements were carried out to ensure that the out-of-field effects under study will not be the result of photons crossing the lead shield or deflected in the cap through the irradiated tissues. To verify this, the NE 2571 ionization chamber was set in the same position as the brain, heart or liver of the irradiated mice and inserted into the lead parallelepiped cap with the same characteristics of the shields used to partly protect the mice to be irradiated. This was repeated with or without a phantom. The estimation of dose into the shield at the different positions, resulting for each organ from the average of 10 measurements showed that, due to primary photons beneath the shields plus scattered radiation from x-ray deflection through irradiated tissues, for a 2 Gy dose at 250 kVp, there was a dose of 4 mGy to the shielded brain, a 7.6 mGy dose to the shielded heart and a 32.1 mGy dose to the shielded liver, corresponding to 0.2%, 0.38% and 1.6% of the total dose, respectively (Figure 1). Measurement of the dose to the liver may be affected by the dimension of the ionization chamber, whose lower extremity was placed very near to the lower shield edge, therefore the 1.6% value could possibly be overestimated.



						Dose (Gy)	Scatter dose		
		SEV	Em	HV	I				
		/mm Cu	/ keV	/V	/mA		Gy	mGy	
BRAIN	H-60	0,082	38	64,9	45	2	0,001148	1,148111	
	H-100	0,29	57,3	102,7	40	2	0,003406	3,405973	
	H-200	1,61	99,3	201,5	20	2	0,006365	6,365132	
	H-250	2,44	121,5	250	15	2	0,004033	4,032682	0,20%
HEART	H-60	0,082	38	64,9	45	2	0,002914	2,913586	
	H-100	0,29	57,3	102,7	40	2	0,006477	6,476612	
	H-200	1,61	99,3	201,5	20	2	0,009365	9,364501	
	H-250	2,44	121,5	250	15	2	0,007615	7,614511	0,38%
LIVER	H-60	0,082	38	64,9	45	2	0,025304	25,30388	
	H-100	0,29	57,3	102,7	40	2	0,03268	32,68006	
	H-200	1,61	99,3	201,5	20	2	0,031562	31,56183	
	H-250	2,44	121,5	250	15	2	0,032009	32,00899	1,60%

Fig 1: Summary of the experimental measurements with the NE 2571 ionization chamber. Table: values of scatter doses to the brain, heart and liver at 60, 100, 200 and 250 kVp.

Therefore, the attenuated and scattered dose was also assessed using gafchromic film. A phantom of polymethyl methacrylate was used to simulate the mouse body at 80 days of age. Dose verification in a plan under the phantom was performed by using appropriately calibrated EBT2 Gafchromic film (Figure 2) (4, 5). EBT2 film is nearly tissue equivalent, with an effective atomic number of 6.84. EBT2 dose range is 0 to 40 Gy.

Before irradiation, EBT2 films are yellow, while after irradiation they become green because of the active layer undergoing polymerization. Films were irradiated for calibration with increasing doses from 1 cGy and up to 10 Gy with a Gilardoni CHF 320 G X-ray generator operated at 250 kVp as described above. Irradiated film pieces were digitalized 48h after exposure. The calibration curve was extrapolated by an interpolation (3 degree) using the red channel (5). The measurements were repeated using the body of an 80-days old mouse as phantom, and identical results were obtained.

The results of these measurements (Figure 2) indicate that for all three shielded organs under examination, the scatter dose received at 250 kVp was 0.95% of the delivered 2 Gy dose, i.e., 19.0 mGy (lower gaf).

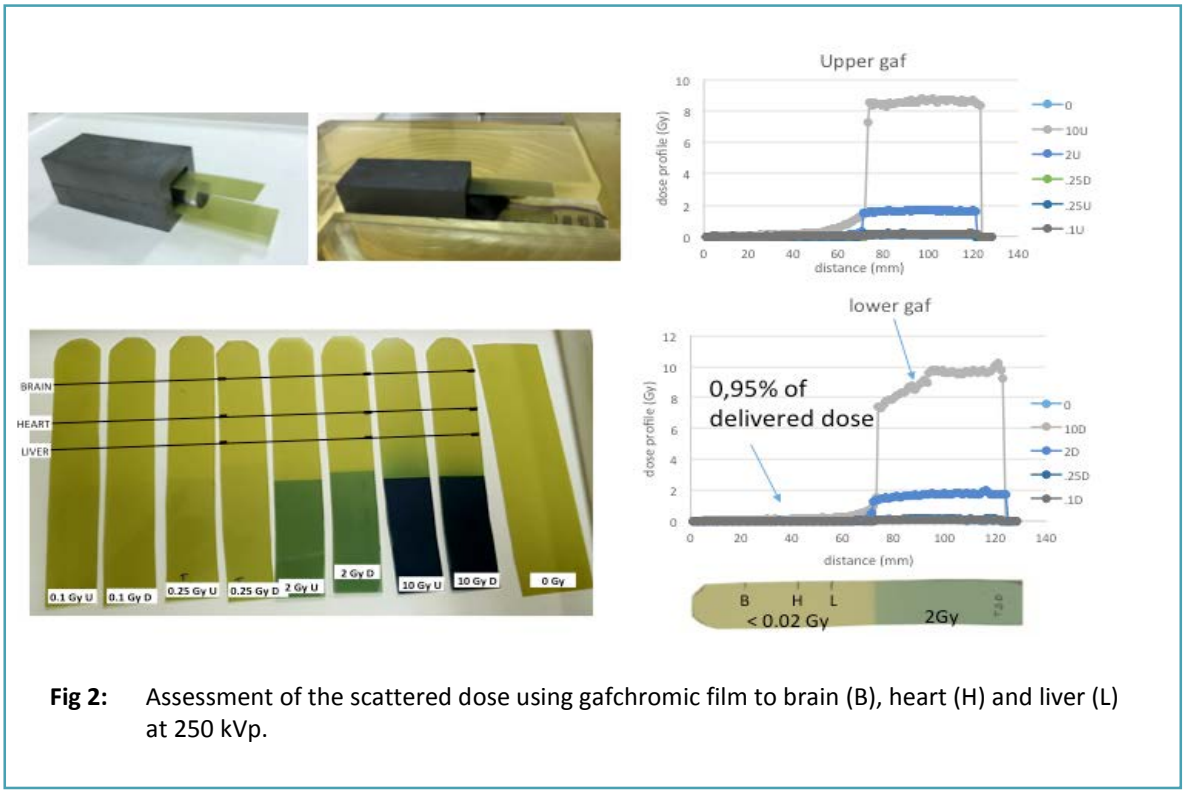


Fig 2: Assessment of the scattered dose using gafchromic film to brain (B), heart (H) and liver (L) at 250 kVp.

In conclusion, with both methods employed there was no significant dose to the shielded organs, including liver.

References:

1. American Association of Physicists in Medicine (2001) AAPM protocol for 40–300 kV x-ray beam dosimetry for radiotherapy and radiobiology. Med Phys 28:868 – 893.

2. Joint Working Party of the British Institute of Radiology and the Institution of Physics and Engineering in Medicine and Biology (1996) Central Axis Depth Dose Data for Use in Radiotherapy (British Institute of Radiology, London), Suppl 25.

3. Mancuso et al. Oncogenic bystander radiation effects in Patched heterozygous mouse cerebellum. Proc Natl Acad Sci U S A. 2008 Aug 26;105(34):12445-50.

4. Strigari et al. Abscopal effect of radiation therapy: Interplay between radiation dose and p53 status. Int J Radiat Biol. 2014 Mar;90(3):248-55.

5. Hartman et al. Gafchromic EBT2 film dosimetry in reflection mode with a novel plan-based calibration method. Med Phys. 2013 Jan;40(1):011720.