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D 9.102 – Detailed specifications of neutron fields to be used

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D9.102 = D5.1Detailed specification of the fields to be used (Specification of the mixed neutron/gamma fields to be used in PODIUM)

Introduction

The main aim of work package 5 is to perform a proof-of-concept of the online dosimetry application from WP3 in a mixed neutron-gamma workplace field. Because access to a real workplace field can be restricted, the optimization of the tools will first be done in a field representative of the workplace field, before moving to the real workplace field.

This deliverable describes the neutron fields that will be used in PODIUM. Whatever field is used, it will always be a mixed neutron/gamma field, since gamma rays are always present together with neutrons.

There are specific difficulties associated with accessing many workplace neutron fields. The primary problems relate to the likely levels of security that will cause difficulty in gaining access for staff that do not have security clearance. Even with security clearance, the level of supervision by staff from the site is likely to restrict the number of people from PODIUM able to enter the workplace. These problems derive from the neutrons typically being generated by highly enriched fuel, spent fuel or weapons-grade materials.

If granted access to a nuclear site, there are likely to be restrictions on the equipment that can be taken in, which will apply most strictly to any items able to take images of the facility. For the PODIUM contract, the need to use video images to identify staff will pose specific problems with access, because agreements not to retain any images may need to be negotiated with the facility in advance.

To be useful to the PODIUM project, the selected fields need to be representative of real workplaces, but also to have relatively high dose rates. The fields will be mixed, so dosimetry of both the neutrons and photons will need to be performed in parallel, which will present additional computational demands. Facilities can be very large, with highly shielded sources, the energies of the neutrons of interest varying from meV to MeV. The necessary application of the energy-dependent w_R for neutrons further complicates the dosimetry. For this reason, a detailed dose map will need to be calculated in advance, with normalization then applied in real-time using installed monitors or some other means of monitoring the source term.

To ensure that the project can achieve results it is foreseen that a scoping exercise is performed in the Public Health England (PHE) calibration laboratory before moving on to a real workplace.

Part 1: scoping exercise at PHE

A ^{241}Am-Be calibration source (UK Secondary Standard) will be moderated using either water or polyethylene shields (Figure 1). These shields may only partially obscure the neutron source, so that there can be significant dose rate gradients in the room. A full MCNP model of the facility already exists, and the fluence-energy distribution of the field has been characterized previously, but this modelling will be extended to more flexible and realistic shielding configuration prior to the measurements. The field will be a mix of fast neutrons from the partially moderated source, and lower energy neutrons from scatter with the shield and calibration room.

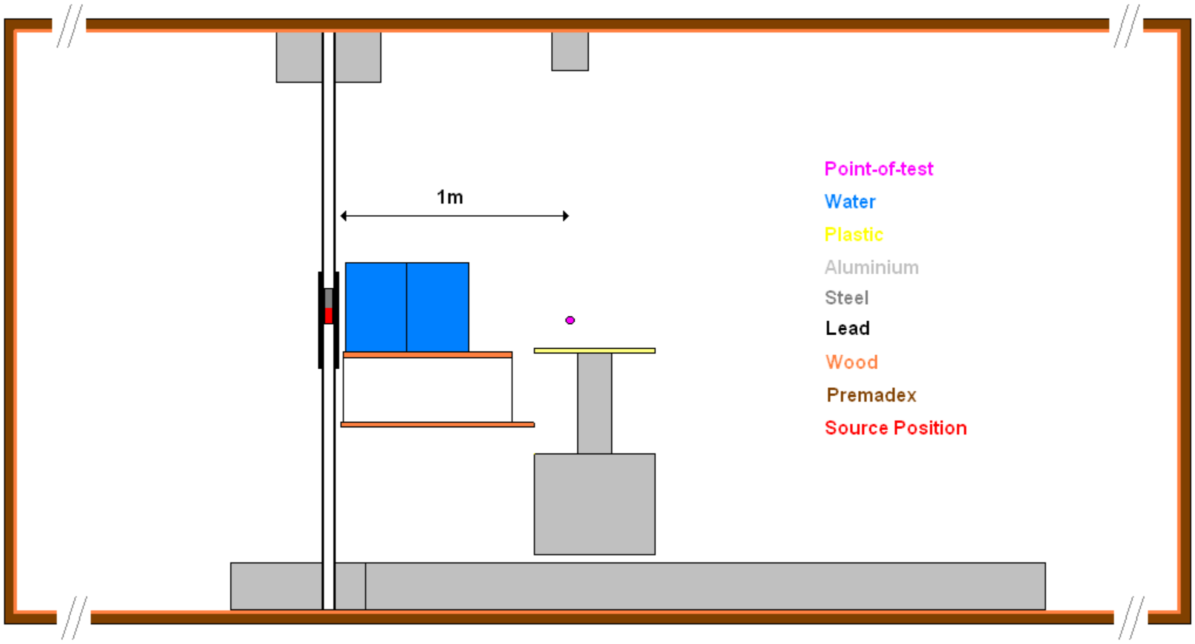

Figure 1: Simulated workplace neutron field at PHE

Current radiation protection controls do not permit people to be inside the PHE facility with the source exposed. This will not be a problem for this test, however: the dose rate map will be built-up in advance, so when people move around within the room, they can be imaged, and their dose rate determined, without receiving an unwarranted radiation dose.

The scoping exercise at PHE will also permit the impact of additional factors to be considered and tested. One such example is the potential effect on doses that is caused by the presence of two or more people in the room: neutron moderation and cross-scatter from one person to the other will perturb the field and hence the dose rates, the magnitude of which needs to be quantified as a function of their locations and relative separations.

An anthropomorphic RANDO® phantom will be used with personal dosemeters mounted on it, to assess the methods using relatively long exposures to achieve significant doses. This will enable the online results to be compared to routine dosemeters for whole body and eye dosimetry, in realistic locations on the body. This phantom will be used in a variety of orientations and positions.

Part 2: real workplaces

The options for real workplaces have been developed, with many options being considered. Inevitably, this is a lengthy and complex process, given the unique nature of the workplaces of interest, and the various security, health & safety considerations and permissions that will need to be agreed in advance between the PODIUM consortium and the potential organizations. Nevertheless, contact has already been made with the sites in Table 1, and negotiations are underway with the hope of making final decisions sometime in Q2 2018.

The strengths and weaknesses associated with each option are summarized in Table 1. The suitability of the field is the main driver for PODIUM; in general, however, access to the site is more complicated for the more interesting fields. Based on the realistic nature of the fields and the relative ease of access, the Research Centre has been selected as the best option, with the fuel enrichment facility acting as a reserve or additional facility to be visited.

Table 1:Summary of potential workplace neutron fields

Workplace	Field(s)	Strengths	Weaknesses
1) Research Centre	• **Transport container with spent UO_2 or MOX fuel**	• **Realistic field where workers get significant doses** • **Relatively easy access**	• **Uncertainties in composition of the transport container and fuel make Monte Carlo simulation difficult**
2) Fuel enrichment facility	• UF_6 storage facility	• Quite high dose rates • Facility where workers get neutron doses • Site interested in the dosimetry • The site has indicated informally that it is interested in taking part	• Site access may not be easy
Weapons facility	• Assembly of block sources in an unused building • VIPER research reactor	• Good collaborative links with the lead scientist • Fields representative of those to which workers are exposed • The site has indicated informally that it is interested in taking part	• Neither field is "real". • Measurements could be made in the field made from assembled blocks, but the field would be only marginally more realistic than the calibration field at PHE • The VIPER reactor would be entirely simulated • Access to the site may be very difficult
Pressurized water reactor	• Fuel rods whilst being removed from pond storage	• Representative of workplaces in the nuclear fuel cycle • Good contacts with the scientists responsible • The site has indicated informally that it is interested in taking part	• Moving source may need to be simulated • Access may be problematic • Fields may not be available on a timescale that fits PODIUM, with a start date unlikely to be possible until at least late 2019
Research proton accelerator	• Proton beam – stray radiation fields	• Good links with scientists who are very interested in the dosimetry • Low security restrictions • Interesting geometries • The site has indicated informally that it is interested in taking part	• High energy fields • Not really representative of typical workplaces • Monte Carlo more complex and uncertain
Fusion tokomak	• Fusion tokomaks	• Scientific establishment with real interest in the fields • Relatively easy access • The site has indicated informally that it is interested in taking part	• Only able to operate in very short pulses • Would need to assume steady state operation and track staff through a real geometry with simulated dose rates • Relatively high energy neutrons
Proton therapy facility	• Proton therapy facility with stray neutron fields	• Facility with a real need to understand its fields • Easy access	• High energy fields • More complex Monte Carlo • Not representative of most current workplaces
Nuclear fuel reprocessing facility	• Spent fuel flask • Reprocessing facility • Pu storage	• Realistic fields where workers get doses • Established contact with links to the EVIDOS project	• Security issues may be too great