AIR²
Access to INFRASTRUCTURES for Radiation protection Research

Special Issue 6
March 2020

CONCERT CORNER

Editorial

Today we publish the second of our Special Issues dedicated to the results of the projects supported by the EJP CONCERT. PODIUM has been selected during the second call for tenders and is dedicated to the development of methods to optimize individual dosimetry. This project is part of a key theme of radiation protection of workers. The results presented here show how PODIUM's partners have met the challenge of setting ambitious goals and achieving them within 24 months. PODIUM is of utmost importance for the EURADOS and EURAMED platforms and offers online access, user-friendly applications and open source data. It should be noted that STORE, the database supported by CONCERT WP6, is widely used for their Data Management Plan.

Dr Laure Sabatier, CEA

The floor to...

PODIUM – Personal Online DosImetry Using computational Methods

Monitoring the individual exposure of workers constitutes an integral part of any radiation protection programme. Individual monitoring of exposed workers to external ionizing radiation is essential in order to ensure safe and satisfactory working conditions, demonstrate compliance with dose limits and the application of the ALARA principle.

At present, personal dosimetry is typically performed by issuing staff with physical dosimeters. These physical measurement devices are part of routine practice, but still have many limitations, both from a practical and from a metrological point of view. The results are usually known only after some delay with passive dosimeters (30-60 days). In addition, performing precise and reliable personal dose measurements in all types of workplace is quite difficult. There are issues with compliance and multiple dosimeters can be mixed up or worn incorrectly. The number and positioning of individual dosimeters is becoming more complex with the new focus on eye lens dosimetry. Also, the uncertainties with the present dosimeters are not negligible. An uncertainty factor of 2 is accepted as good practice for low doses and for neutron fields in particular the uncertainties are even higher.

On the other hand, computational techniques are evolving rapidly. In the past, standard mathematical phantoms were used, while now very detailed voxel and Non-Uniform Rational B-splines (NURBS) phantoms are available. In addition, with increasing computational power, such calculations can be performed faster and faster.

The objective of this project was to improve occupational dosimetry by an innovative approach: the development of an online dosimetry application based on computer simulations without the use of physical dosimeters.

This was done using a combination of (i) monitoring of the position of workers in real time and (ii) the spatial radiation field, including its energy and angular distribution. The movement of workers needed to be monitored and transferred to a calculation application. Modern cameras and software were used for this. The radiation field map of the workplace can be based on analytical calculations or more advanced Monte Carlo calculations. A variety of computational body phantoms were used, assuming various postures inside the radiation field and having different body statures, so that also organ doses can be determined. When combined with fast simulation codes, the aim was to perform personal dosimetry in real-time. Operational quantities and protection quantities and even radiosensitive organ doses (e.g. eye lens, extremities) were assessed.

Because of the limited time frame, we simultaneously used an intermediate approach with pre-calculated fluence to dose conversion coefficients for phantoms of different statures and postures. This approach provided us with the first step towards online dosimetry based on simulations.

Photo: SCK•CEN

The PODIUM consortium (left)

Dr. Ir. Filip Vanhavere PODIUM Coordinator, SCK•CEN, Belgian Nuclear Research Centre (right)

Keywords:
Online dosimetry, computational dosimetry, neutron dosimetry, interventional radiology, individual monitoring, ALARA, phantoms

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Duration:
24 months

Total project budget:
1.4 M€

Project website:
https://podium-concerth2020.eu/

Open Access of produced data:
All publications will be open access, all deliverables are open access, part of the data produced are uploaded in STORE.

Related to:
EURADOS

Contents:

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

Dose simulations input: staff movement monitoring and radiation field mapping

We have set up two indoor position systems (IPS) to track monitored people. The first system is based on the use of a Kinect 2.0 depth sensor camera with an adapted software. The system reduces jittering by incorporating a filtering algorithm based on Holt Double exponential method, and improves the identification of workers by introducing several specific methodologies, depending on the workplace. This one Kinect system has been selected to be used in most tests within WP4 and WP5, because of its ease of use and installation.

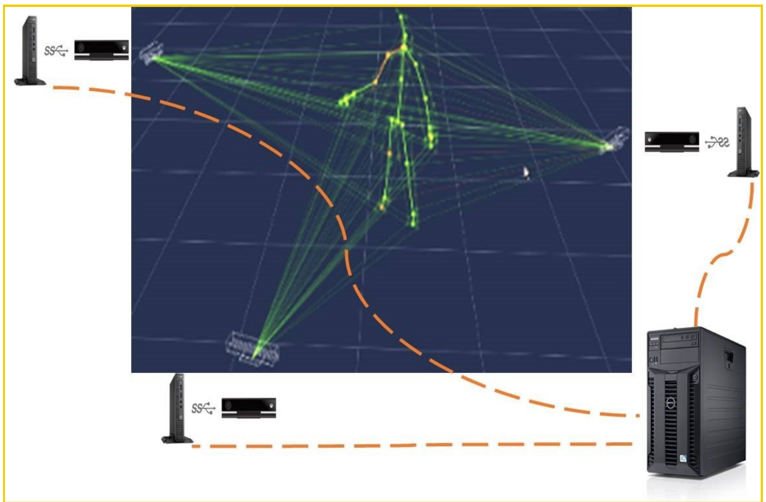

Photo: UPC

The set-up of the multi camera system

The second system is a two-camera solution based on the use of two Kinect 2.0 depth sensor cameras and an adapted software which is capable to fuse the images of the two cameras and thus reduce occlusion problems and increase the field of view of the cameras.

Both systems are ready for the purpose of the feasibility study but they do not allow the tracking of some objects such as the ceiling shielding or the C-arm movement, which is, sometimes, needed for the dose calculations.

As regards interventional radiology workplaces the required information and the foreseen data sources have been identified. In particular, for the calculations the most reliable way to gather the required information is the RDSR report. The PODIUM application uploads the information from the RDSR and transforms it to be used as input for the dose calculation. A sensitivity analysis on the impact of different parameters on the operator dose has been carried out to optimize the size of the radiation field lookup table.

Photo: UPC

Maria Amor Duch

For neutrons, the real time Monte Carlo method is not feasible due to the time constraints being unrealistic for such computationally intensive simulations, as well as problems with the calculation method itself. Therefore, a lookup method is used where the workplace simulations must be performed before the application of the proposed real time dosimetry system. The workplace characterization will result in lookup tables defined on grids with locational- and directional- (the facing direction of the individual) dependent effective dose conversion coefficients. This system will depend on a monitor to scale the lookup value with the instrument's reading. The lookup table is highly dependent on the workplace and the neutron sources, but can be calculated in advance using the Monte Carlo method without the time constraints of a real-time system.

Photo: SCK•CEN

The tracking of a worker in a nuclear installation

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Dose simulations using computational phantoms and Monte Carlo methods

WP2 has provided a set of computational phantoms with a wide range of anatomies and postures. Thanks to the 3 female voxel phantoms and to the IPP tool, simulations could be performed which represent occupationally exposed workers and the real working scenarios. On the one hand, we have made use of well established female voxel phantoms from the HGMU family, which can serve as reference.

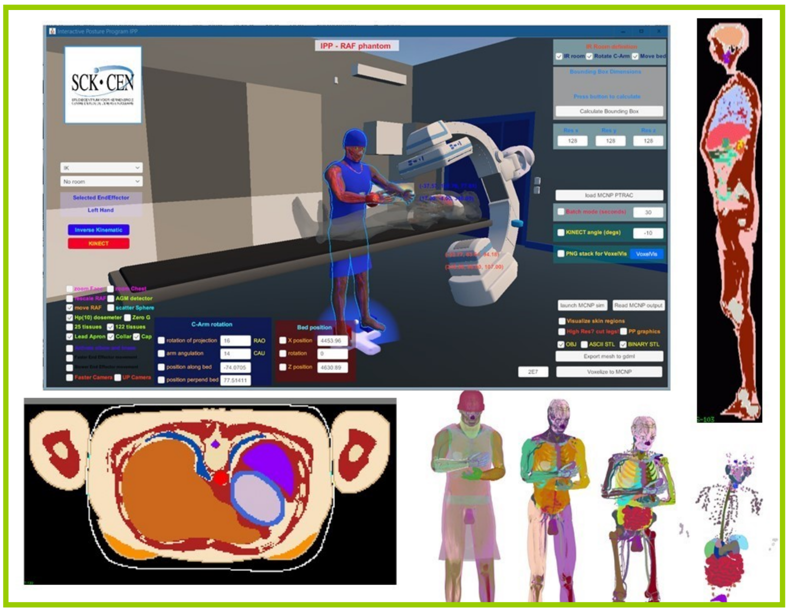

Photo: HMGU, SCK•CEN

Phantom development

On the other hand, we have made use of the RAF phantom, which is flexible in his posture. We expect that with this variety of phantoms, we have made PODIUM's approach to dosimetry not only more innovative, but also more individualized. Furthermore, WP2 has provided a library of pre-calculated fluence to dose conversion coefficients for phantoms having reference statures and non-reference postures as well as for phantoms having various statures.

The numerical data of the conversion coefficients have been uploaded to the STORE database.

Photo: HMGU

Maria Zankl

Two fast MC systems have been developed for application in hospitals for interventional radiology procedures. The two tested codes provided acceptable results in simulation times that can be lower than 20 s (CPU/GPU use time) per simulated irradiation event. It is worth mentioning that one of the main advantages of MCGPU-IR is the calculation of the effective dose, E, but this cannot be verified by comparison with dose measurements because physical detectors can only determine the operational quantities.

The computing time required to calculate E is much lower than to calculate $H_p(10)$ with this code. Likewise, when compared to PENELOPE/penEasy, MCGPU-IR offers the advantage to directly calculate E.

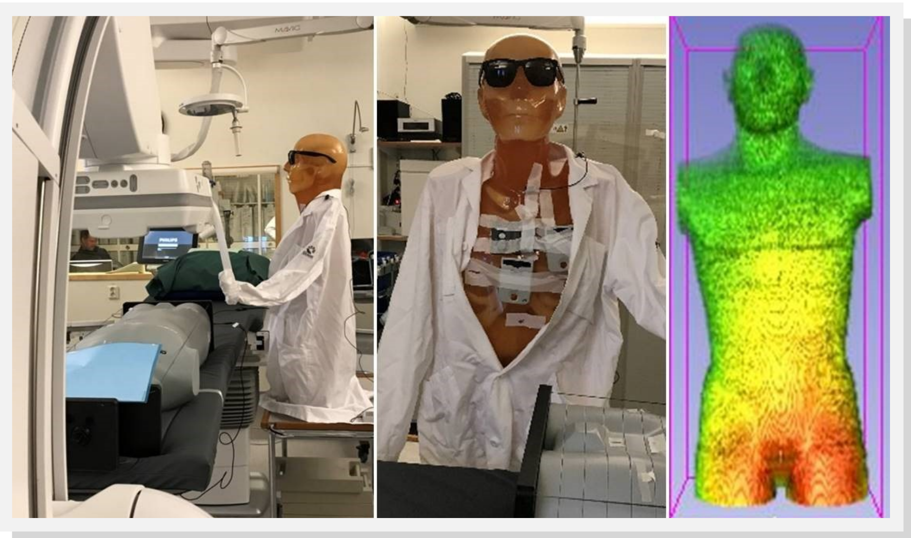

Photo: LU, UPC

Validation of the simulations with phantoms in a hospital environment

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Development of the online dosimetry application

The goal of WP3 was to develop a user-friendly application that combines all the developments made within the PODIUM project and allows non-specialist users to assess and follow up staff doses. A set of requirements was listed for this so-called Dosimetry online Calculation Application (DCA).

The technical modules for staff tracking and dose calculation were developed as external modules by the PODIUM partners. However, they had to be connected with the DCA.

Users work with the DCA by logging in to a user-friendly web application. Each user has its predefined roles. The whole process flow is implemented in a logic and easy to follow way. First room, radiation source and worker data have to be inserted in the database. Then a procedure can be defined and created. Once connection with the locally installed tracking system is made, the procedure can be started.

After finishing the procedure, the tracking file is uploaded automatically by the tracking system. The RDSR file containing the radiation source data has to be uploaded manually because direct communication with the C-arm is not yet possible. Then the dose can be calculated with the dose calculation method of interest by connecting with the locally or remotely installed dose calculation system.

Olivier Van Hoey

Photo: SCK•CEN

Finally, the radiation protection expert and workers can consult the calculated doses. The DCA was already successfully tested in clinical practice. The first tests were always partial because the DCA was still under development. However, it proves the feasibility of the PODIUM approach.

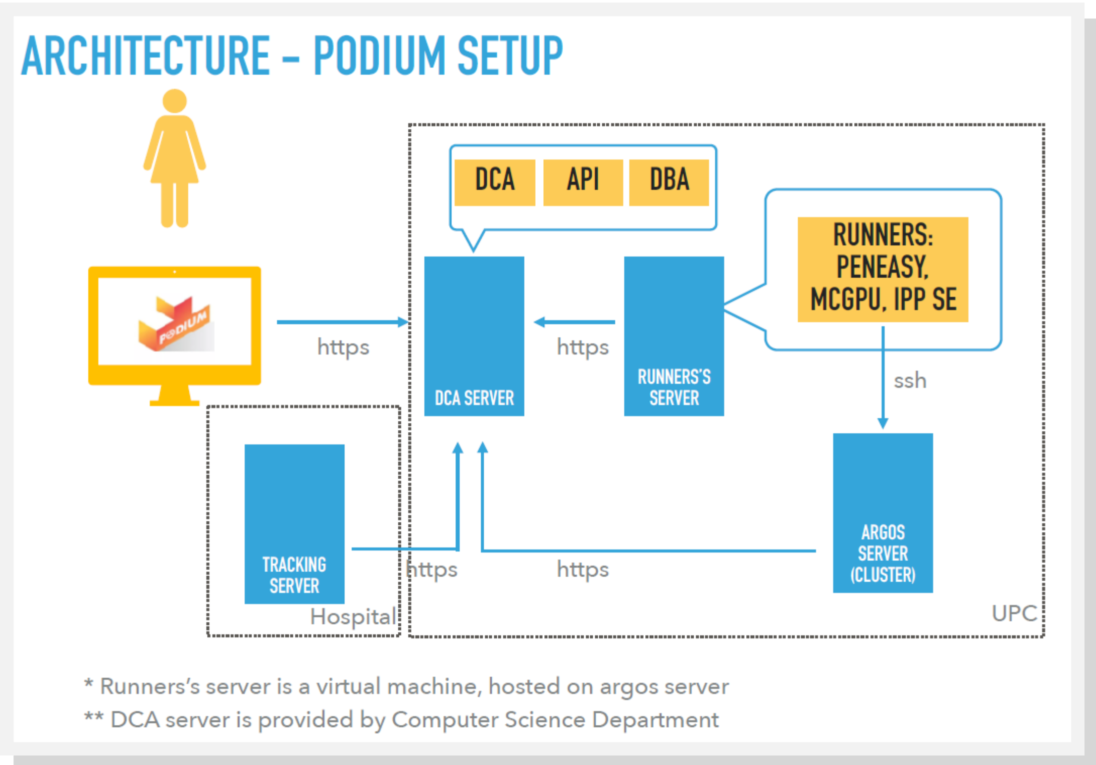

Photo: UPC

Architecture of the PODIUM DCA

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Assessment and validation of the online dosimetry application in hospitals

A series of experimental set-ups was first used to test the online application in a systematic manner. The operator's movement tracking was tested on site in an interventional room, by mimicking operator movements without patients involved.

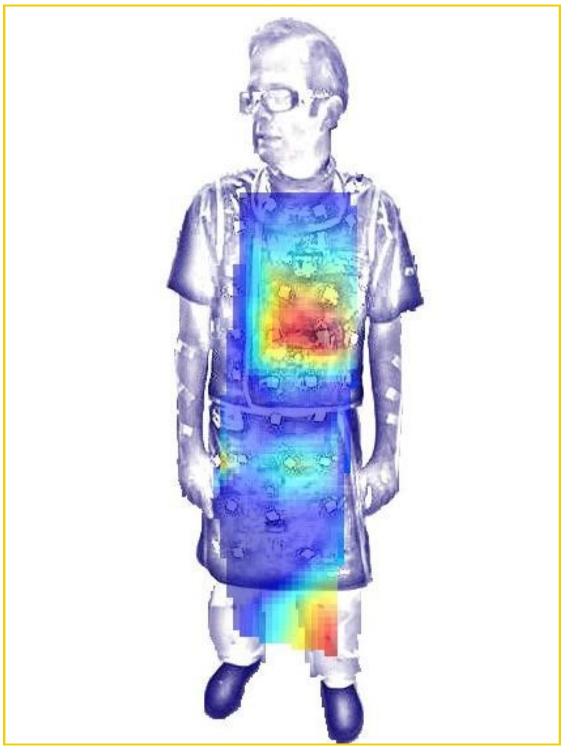

Photo: LU

Mapping of the doses of an operator in interventional radiology

The validation experiments were performed using clinical X-ray equipment, where X-ray field size and tilting of the X-ray tube was altered. The operator was simulated using phantoms. In order to simulate the patient, an anthropomorphic phantom was used. During the experimental set-ups, detailed measurements, from different positions using active and passive dosimeters on the dummies, were performed in order to validate the computed doses. The measurements gave useful information to improve the simulations, source specifications and geometry mapping.

Secondly, a full scale feasibility test in clinical settings during real patient treatment in hospitals was performed. Different procedures were chosen including commonly performed vascular and cardiovascular procedures. The staff doses of different body parts were measured using active and passive dosimeters on relevant positions on the operators. This part of the project was conducted at the St James´s hospital, Dublin, Ireland and at the Skåne University Hospital, Sweden. The clinical environment is necessary in order to gather appropriate information on the performance of an online dosimetry application in the hospital.

Photo: LU

Anja Almen

The experimental and clinical tests indicated development needs in order to get the full clinical relevance of the online dosimetry application. The possibilities and limitations of the application were explored, taking into account the clinical situation. These first validations in the clinic serve as a valuable input to the improvement of the system. The experience gained from the clinical validation measurements has been used as to develop the recommendations on future needs. The interventional radiology/cardiology workplace is one of the most complex situations for personal dosimetry. Therefore, it was ambitious, yet highly worthwhile, to try the proof-of-concept PODIUM approach in this field.

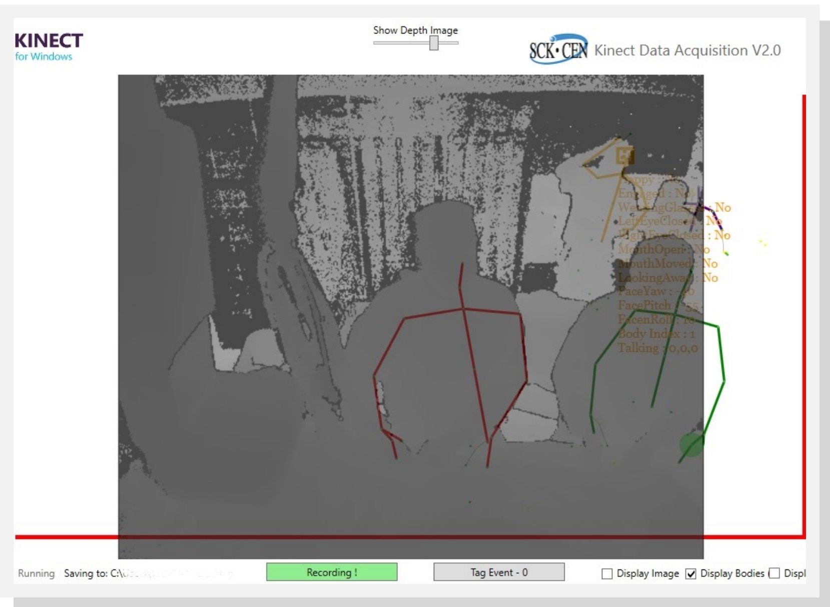

Photo: SJH, LU, SCK•CEN

Body Basics Screenshot Multiple skeleton

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Assessment and validation of the online dosimetry application in mixed neutron-gamma workplace fields

Mixed neutron/photon fields were identified as an area where online dosimetry might be a very useful technique, but also one where there could be significant problems. The calibration laboratory at PHE was envisaged as the first stage of this testing process, and the facility at SCK•CEN was the most promising for a real feasibility study.

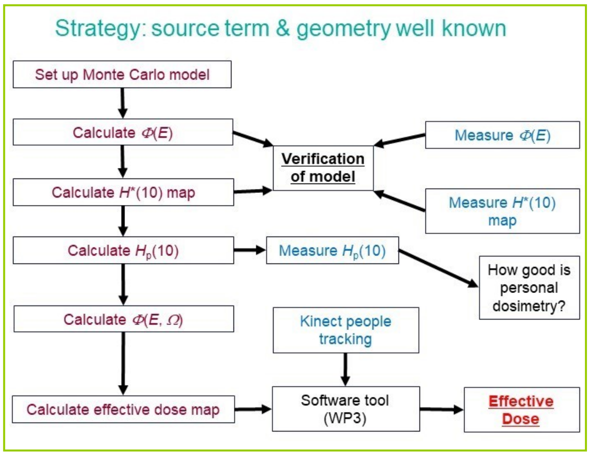

Photo: PHE

Strategy to obtain effective dose where the workplace is well known in terms of the source term, the geometry and the materials

Different approaches were needed for the simulated workplace and the real workplace, because the source term was very well known in the case of the simulated workplace but was not for the real workplace. Evaluation of the Monte Carlo model was a crucial aspect of this work package. Two methods were proposed: experimental spectrometry and surveying using neutron survey instruments. The first of these proved a useful aid to checking the Monte Carlo spectra. The use of survey instruments was an important validation of the dose rates, but such instruments have energy and direction dependences of response. However, for both fields it can be concluded that the Monte Carlo model is accurate for $H^*(10)$ to within about 15%, which in the context of conventional personal dosimetry, where responses need to be in the range 0.5 -2.0, is good performance.

Personal dosimeter exposures were performed for comparison with the online results. These were not used as validation of the Monte Carlo because personal dosimeters are not accurate enough to validate the results. The personal dosimeters were found to show significant variations in their readings for the same exposure, so it is evident that conventional assessments of personal dose equivalent are subject to considerable uncertainty.

Photo: PHE

Rick Tanner

Online dosimetry, by making direct estimates of effective dose, offers significant potential for better estimates of workplace risk.

To obtain estimates of effective dose in a neutron-rich workplace has some computation time problems, but the definition of effective dose poses greater difficulty. These issues make direct estimate of real-time neutron effective dose in the workplace *via* computations in anthropomorphic phantoms unfeasible at present. To overcome this, innovative methods have been developed to produce an effective dose map for neutron workplaces. These novel methods are one of the main achievements: effective dose rate maps for location and orientation were generated for use with people tracking. Applying these dose maps yielded effective dose estimates of a few µSv, whereas personal dosimeters generally have reporting thresholds of 100 µSv or higher, with good dose estimate precision only being achieved above about 1 mSv.

PODIUM has demonstrated that the look-up table approach for mixed fields is feasible and offers the potential for significantly more accurate assessments of risk in neutron-rich workplaces. This innovative method was required because it was recognized from the outset that neutron effective doses could not be modelled in real time in complex geometries using voxel phantoms in the Monte Carlo model.

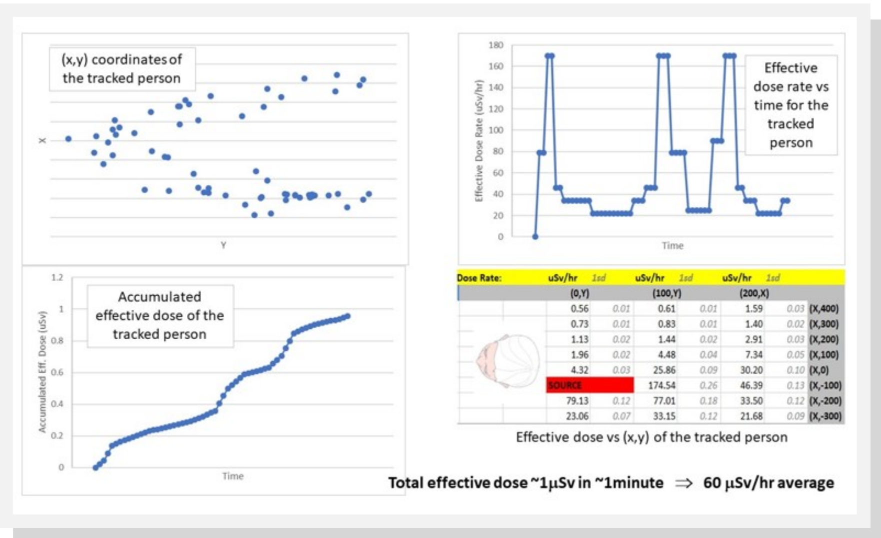

Photo: PHE

Result of people tracking in a neutron facility

Public Health England

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Dissemination of the project results

A dedicated Work Package was set-up for the dissemination of the project results. The main objective of this WP was to stimulate the optimal application of the ALARA principle in various workplaces for the planning of occupational exposure as well as the education of exposed workers. Moreover, an exploitation plan for the future development of the project results was set up.

Photo: PODIUM

In order to obtain the maximum impact of the on-line application in combination with the ALARA principle in occupational dosimetry, a dedicated Work Package (WP6) was proposed.

In order to accomplish these objectives the following tasks were executed:

• to seek advice for the orientation of the project by setting up an advisory board. Members included experts and representatives from a wide array of scientific fields and international bodies: the International Commission on Radiological Protection (ICRP), the European Commission (EC), the Belgian Federal Agency for Nuclear Control (FANC) and the International Labour Organization (ILO).

Photo: EEAE

Eleftheria Carinou

• to set-up an exploitation plan for the developed applications,

• to explore the possibilities of setting approval criteria for online dosimetry as legal dosimetry,

• to present the results of the project through a workshop,

• to participate in national and international conferences, workshops, fora and social media networks.

<u>Conclusion</u>

PODIUM proved the feasibility of performing personal dosimetry of occupationally exposed workers using computational methods. Applying this novel approach would give significant advantages compared to present physical dosimeters, with possible first use as an ALARA tool. Future improvements can certainly pave the way for the application of the innovative PODIUM approach as an approved dosimetry service.

Photo: EEAE

The 19th workshop of the European ALARA Network (EAN) was a joint meeting with the PODIUM project consortium. It was hosted by the Greek Atomic Energy Commission (EEAE) in Athens, Greece from 26th to 29th of November 2019.

ΕΕΑΕ ΕΛΛΗΝΙΚΗ ΕΠΙΤΡΟΠΗ ΑΤΟΜΙΚΗΣ ΕΝΕΡΓΕΙΑΣ GREEK ATOMIC ENERGY COMMISSION

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Published to date:

Issue	Exposure platforms	Databases, Sample banks, Cohorts	Analytical platforms, Models & Tools
Oct 2015, #1	FIGARO	FREDERICA	RENEB
Nov 2015, #2	B3, Animal Contamination Facility	The Wismut Cohort and Biobank	The Hungarian Genomics Research Network
Dec 2015, #3	Pulex Cosmic Silence	STORE	METABOHUB
Feb 2016, #4	SNAKE	French Haemangioma Cohort and Biobank	Dose Estimate, CABAS, NETA
Mar 2016, #5	Radon exposure chamber	3-Generations exposure study	PROFI
Apr 2016, #6	Biological Irradiation Facility	Wildlife TransferDatabase	Radiobiology and immunology platform (CTU-FBME)
May2016, #7	CIRIL	Portuguese Tinea Capitis Cohort	LDRadStatsNet
Jun 2016, #8	Mixed alpha and X-ray exposure facility	Elfe Cohort	ERICA Tool
Jul 2016, #9	SCRS-GIG	RES³T	CROM-8
Sep 2016, #10	Facility radionuclides availability, transfer and migration	INWORKS cohort	France Génomique
Oct 2016 #11	LIBIS gamma low dose rate facility ISS	JANUS	Transcriptomics platform SCKCEN
Nov 2016, #12	Microtron laboratory	EPI-CT Scan cohort	CATI
Dec 2016, #13	Nanoparticle Inhalation Facility	UEF Biobanking	The Analytical Platform of the PREPARE project
Feb 2017, #14	Infrastructure for retrospective radon & thoron dosimetry	Chernobyl Tissue Bank	HZDR Radioanalytical Laboratories
Special Issue 1	1st CONCERT Call: CONFIDENCE, LDLensRad, TERRITORIES	1st CONCERT Call: CONFIDENCE, LDLensRad, TERRITORIES	1st CONCERT Call: CONFIDENCE, LDLensRad, TERRITORIES
Mar 2017, #15	Alpha Particles Irradiator Calibration Laboratory at KIT		SYMBIOSE
Apr 2017, #16	Changing Dose rate (SU) Low dose rate (SU)		Advanced Technologies Network Center
May 2017, #17	Chernobyl Exclusion Zone	Chernobyl clean-up workers from Latvia	BfS whole and partial body Counting
Jun 2017, #18	MELAF	Belgian Soil Collection	INFRAFONTIER
Jul 2017, #19	MICADO'LAB	Estchern Cohort	ECORITME
Sep 2017, #20	DOS NDS		CERES
Oct 2017, #21	CALLAB Radon Calibration Laboratory		CORIF
Nov 2017, #22	Calibration and Dosimetry Laboratory (INTE-UPC)	German airline crew cohort	Centre for Omic Sciences (COS)

Future events:

CONCERT Short Courses

9-13 March 2020

Radiation Protection: Basics and Applications,
Forschungszentrum Jülich, Germany
Contact:
Ralf Kriehuber

15-29 March 2020

Monitoring strategies applied in NORM involving industries – evaluation of occupational exposure and environmental impact,
Central Mining Institute, Katowice, Poland
Contact:
Boguslav Michalik

16-27 March 2020

Health effects induced by radiation and space conditions,
SCK•CEN Mol, Belgium
Contact:
Sarah Baatout

30 March 2020

EU CONCERT Radiation Protection Research Projects and UK NIHR HPRU in Chemical and Radiation Threats and Hazards Medical Radiation Theme - Final Stakeholder Dissemination Meeting,
Newcastle, United Kingdom
Contact:
Liz Ainsbury

20 April-1 May 2020

Assessment of long-term radiological risks from environmental releases,
Technical University of Denmark, Risø Campus, Denmark
Contact:
Kasper Andersson

18-29 May 2020

Modelling radiation effects from initial physical events,
University of Pavia, Italy
Contact:
Andrea Ottolenghi

See also on CONCERT website

Editorial Committee: Maria Panagiotopoulou, Jean-Michel Dolo, Laure Sabatier

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Access to INFRASTRUCTURES

Issue	Exposure platforms	Databases, Sample banks, Cohorts	Analytical platforms, Models & Tools
Published to date:			
Dec 2017, #23	NMG	Techa River Cohort (TRC)	iGE3
Special Issue 2	MEDIRAD	MEDIRAD	MEDIRAD
Feb 2018, #24	UNIPI-AmBe	Greek interventional cardiologists cohort	SNAP
Special Issue 3	2nd CONCERT Call: LEU-TRACK, PODIUM, SEPARATE, VERIDIC, ENGAGE, SHAMISEN-SINGS	2nd CONCERT Call: LEU-TRACK, PODIUM, SEPARATE, VERIDIC, ENGAGE, SHAMISEN-SINGS	2nd CONCERT Call: LEU-TRACK, PODIUM, SEPARATE, VERIDIC, ENGAGE, SHAMISEN-SINGS
Mar 2018, #25	IRRAD	MARiS	BIANCA
Apr 2018, #26	Forest observatory site in Yamakiya	BBM	OEDIPE
May 2018, #27	Belgian NORM Observatory Site	The German Thorotrast Cohort Study	VIB Proteomics Core
Jun 2018, #28	CERF	Mayak PA worker cohort	Geant4-DNA
Jul 2018, #29	TIFPA	RHRTR	D-DAT
Sep 2018, #30	HIT	The TRACY cohort	COOLER
Oct 2018, #31	PTB Microbeam	The BRIDE platform	BRENDA
Nov 2018, #32	AGOR Facility at KVI-CART LNK		MARS beamline at SOLEIL
Dec 2018, #33	PARISII	The ISIBELa cohort	CIEMAT WBC
Feb 2019, #34	The MIRCOM microbeam	The ISE cohort	EFFTRAN
Special Issue 4	NSRL	LSAH & LSDA	GeneLab
Mar 2019, #35	IRSE Experimental Farm	The MWF database	DSA Environmental Laboratory
Apr 2019, #36	PG stack at Barreiro, Portugal	CONSTANCES	The MCDA Tool
May 2019, #37	LERF	IMMO-LDRT01 cohort	Radiochemical and Radioactive Analysis Laboratory (INTE-UPC)
Jun 2019, #38	FAIR	The BACCARAT study	CIEMAT *In Vitro* Internal Dosimetry Laboratories
Jul 2019, #39	AMBIC	LSS	LRM
Sep 2019, #40	FRM II	REQUITE	TU Dublin Analytical Platform
Special Issue 5	CONFIDENCE	CONFIDENCE	CONFIDENCE
Special Issue 6	PODIUM	PODIUM	PODIUM

Future events:

Other Events

19-24 April 2020
ICRER: 5th International Conference on Radioecology & Environmental Radioactivity, Amsterdam, The Netherlands

19-24 April 2020
IM2020: International Conference on Individual Monitoring, Budapest, Hungary

5-8 May 2020
1st ISORED scientific and organisation meeting, Sitges, Spain

27-29 May 2020
6th NERIS workshop: Operational and research achievements and needs to further strengthen preparedness in emergency management, recovery and response, Barcelona, Spain

28 September-2 October 2020
ERPW2020: European Radiation Protection Week 2020, Estoril, Portugal
Deadline for abstract submission: 31st March 2020