

PROJECT FINAL REPORT

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4.1 Final publishable summary report

- An executive summary

The medical staff that carries out interventional radiology and cardiology (IR/IC) procedures is likely to receive significant radiation doses to their hands, or parts of their body not covered with protective equipment, as they are close to the X-ray field. The dose range for the same kind of procedure varies a lot, since there are many factors affecting extremity doses. In addition, there is evidence that eye lens doses can be high in IR/IC, and cases of lens opacities and cataract have been reported in recent years. Besides, a lack of appropriate equipment is also identified in the field of active personal dosimeters (APD) for typical fields in IR/IC. Very few devices can detect low energy fields, and none of them are really designed for working in pulsed radiation fields. In the field of nuclear medicine (NM) the extremity doses to the medical staff are also known to be very high. One can highlight the difficulties in estimating the dose distribution across the hands, and there is a need for better knowledge of doses received during the main tasks of a nuclear medicine department, especially using unsealed sources. The ORAMED project, (www.oramed-fp7.eu) was set up to optimize the working procedures in these medical fields with respect to radiation protection. The project was structured in 5 work packages:

- Extremity and eye lens dosimetry in IR and IC
- Development of practical eye lens dosimetry
- Optimization of the use of APDs in IR and IC
- Extremity dosimetry in NM
- Training and dissemination

A coordinated measurement program in European hospitals was organised both in IR/IC and NM departments. Moreover, simulations of the most representative workplaces/procedures were performed to determine the main parameters that influence the extremity and eye lens doses. Next to these, some dedicated studies on improving the eye lens dosimetry and active personal dosimetry were conducted.

The main conclusions can be summarized as follows.

Based on the measurement and simulation results, a series of practical guidelines and training packages were developed. The influence of the different radiation protection measures (such as the lead shields) has been quantified, and clear monitoring requirements have been formulated for a series of medical procedures.

A formalism for the use of the operational quantities for eye lens dose measurements has been worked out (calibration phantom, conversion coefficients, type test procedures,...). A dedicated eye lens dosimeter has been developed during the project and is now commercially available to be used in the hospitals.

Different existing APDs have been tested for the first time under conditions that are representative of the conditions met in clinical practice (e.g. pulsed fields, low energies), and a series of guidelines for the use of these APDs in IR/IC have been made. Moreover, an improved APD device designed specifically for IR/IC fields has been developed.

The extensive measurement and simulation campaign for extremity doses in NM lead to a systematic evaluation of the different radiation protection measures. These are condensed in a series of practical guidelines to be used. The dose distribution across the hands of the technologists and the physicians was characterised, and recommendations for routine monitoring have been formulated.

The outcome of the ORAMED project will lead to an optimisation of the radiation protection standards for medical staff. The practical guidelines that have been developed will be used by medical staff in hospitals for many years to come. In particular, the developments on the eye-lens dosimetry and the active personal dosimeters will improve the practical measurement capabilities in the field.

- A summary description of project context and objectives (not exceeding 4 pages).

Context

Interventional radiology and cardiology

The staff that carries out interventional procedures is likely to receive significant radiation doses to their hands, or parts of their body not covered with a protective apron, as they are close to X-ray tubes. The doses for this kind of procedures vary a lot, since there are many factors affecting extremity doses such as protective devices, X-ray geometry and spectra, the scattered radiation from the patient, etc.

There are cases mentioned in the literature where the extremity doses can approach the dose limits. In these cases either the high workload or the lack of a proper radiation protection policy are responsible for the high doses observed.

Routine monitoring of extremities is difficult, since “the most exposed area” according to ICRP recommendations cannot easily be found. In most cases only finger or hand doses are reported; doses to the eye lens, legs or thyroid have not been evaluated. In some studies (especially when no protective shielding on the couch is used) doses to the legs can be even higher than doses to the hands. Even when ring/wrist dosimetry is used for extremity monitoring the position of the dosimeter is not clear. There is evidence that eye lens doses are high in interventional radiology, and cases of lens opacities and cataract have been reported in recent years. However, eye lens doses are never measured in routine applications, and in addition very few data can be found in the literature. There is no suitable dosimeter available and the standards for the operational quantity measurements are not complete. This situation is partly due to the lack of conversion coefficients and a suitable calibration procedure.

A lack of appropriate equipment is also identified in the field of active personal dosimeters (APD) for typical fields in interventional radiology and cardiology. Very few devices can detect low energy photon fields, and none of them are really designed for working in pulsed radiation fields.

Nuclear medicine

The literature concerning radiation exposure and protection of nuclear medicine staff is much more limited than in the case of interventional radiology and mostly refers to conventional diagnostic nuclear medicine.

As a consequence of the definition that the dose limit for the skin has to be applied to ‘the dose averaged over any area of 1 cm² regardless of the area exposed’ it is advisable to measure the local skin dose at the location with presumably the highest exposure. This requirement is the central dilemma of extremity dosimetry and causes severe practical difficulties. In daily practice when preparing and administering radio-pharmaceuticals in nuclear medicine it is not easy to comply with that requirement since it is often not known which part of the hand receives the highest dose. Moreover, the dose distribution over the hand may vary during a single process as well as when various workers perform the same procedure.

Unsealed radiation sources are being increasingly used in nuclear medicine for radiation therapy, in particular, nuclides that emit beta or mixed beta/gamma radiation. For example, inflammatory joint

diseases are treated by radiosynoviorthesis (RSO) by injecting ^{90}Y , ^{186}Re or ^{169}Er -solutions into the joints. Recently, radioimmunotherapy (RIT) using ^{90}Y -labelled antibodies for treating malign lymphoma has been introduced in clinical routine. Another promising method, employing ^{90}Y or ^{177}Lu , is peptide receptor guided radiotherapy (PRRT) of neuroendocrinic tumours. Considering the preferential use of beta emitters, the dosimeters must be appropriate for beta radiation, taking into account both the energy spectra of the nuclides and the spectral dose response of the dosimeter.

This means that in nuclear medicine therapy, staff may be exposed to high doses, even exceeding the annual limit of the dose to the skin of 500 mSv. Thus, adequate safety measures including an accurate individual monitoring of the personnel are a strict requirement.

It should be pointed out that most general official personal monitoring databases, such as UNSCEAR (<http://www.unscear.org/>) or ISOE (<http://www.isoe-network.net/>), do not include extremity doses and that many countries with nuclear medicine services do not have authorised ring dosimetry services. Furthermore, the data available in official national registers are much lower than the estimated doses in research studies, which probably means that monitoring is not being done correctly. Through the dissemination of the ORAMED results and the training, we will aim at the improvement of the radiation protection in these fields.

Objectives

The ORAMED project proposes to develop methodologies for better assessing and reducing exposures to medical staff. This general objective is being achieved through the development of 5 main topics, structured in 5 work packages.

WP1: Extremity dosimetry and eye lens dosimetry in interventional radiology and cardiology

WP2: Development of practical eye lens dosimetry

WP3: Optimization of the use of active personal dosimeters in interventional radiology and cardiology

WP4: Extremity dosimetry in nuclear medicine

WP5: Training and dissemination

The objective of WP1 was to obtain a set of standardized data on doses for staff in interventional radiology and cardiology and to optimize staff protection. A coordinated measurement program in different hospitals in Europe has been done to help towards this direction. Moreover, simulations of the most representative workplaces/procedures in interventional radiology and cardiology were performed to determine the main parameters that influence the extremity and eye lens doses.

The objective of WP2 was to establish a sound theoretical and experimental basis to assess eye lens doses. This implied the need to revise the approach for the definition and calculation of conversion coefficients for $H_p(3)$. This was done using the Monte Carlo codes MCNPX and PENELOPE during the first two years of the project. The decision was motivated by two factors: a- the evidence of a higher incidence of lens opacities and cataracts for a given exposure, compared to what was foreseen in the past and, at the same time, b- the lack of an up-to-date data and procedures for a sound methodology for eye lens dose assessment, both in the official ICRP-ICRU documents and in the operative guidelines. A second important objective was to develop a practical eye lens dosimeter. During the third and last year of the project a final design of an eye lens dosimeter was produced. In addition, a guide for type testing and calibration of eye lens dosimeters was implemented. Finally, after the characterization of the prototype, it was also used in a trial campaign in some European Hospitals during IR/IC procedures.

The objective of WP3 was to optimize the use of active personal dosimeters (APDs) in interventional radiology. Interventional radiology procedures can be very complex and they can lead to relatively high doses to medical staff that stand close to the primary radiation field and are mostly exposed to radiation scattered by the patient. Very few devices can detect low energy radiation fields and none of them are specially designed for working in pulsed radiation fields. Therefore, an extensive test programme has been performed, leading to specific guidelines for the use of APDs. Finally, taking into account the aforementioned tests and the characteristics of the X-ray fields used in IR/IC, a new device with an improved response under such conditions has been developed.

The objective of WP4 was to detect the most exposed part of the skin by measuring the extremity doses and dose distributions across the hands of the medical staff working in nuclear medicine departments. Afterwards the most suitable position of an extremity dosimeter had to be assessed. To achieve this, an extensive measurement and simulation program was performed in many European hospitals.

The last objective of the project (WP5) was to design and develop an accurate teaching and knowledge dissemination program and to make sure that the conclusions and recommendations of the project are transmitted to the stake-holders, mainly medical staff, radiation protection officers, dosimetry services and authorities in the field. The main dissemination activities include the publication of reports and scientific articles together with the preparation of training material.

- A description of the main S&T results/foregrounds (not exceeding 25 pages),

WPI: Extremity dosimetry and eye lens dosimetry in interventional radiology and cardiology

1. Measurement campaign

a. List of procedures

The list of procedures includes 3 cardiac and 5 general interventional diagnostic and therapeutic examinations. More specifically, the list is composed of cardiac angiographies (CA) and angioplasties (PTCA), radiofrequency ablations (RFA), pacemaker and cardiac defibrillator implantations (PM/CD), angiographies (DSA) and angioplasties (PTA) of the lower limbs (LL), the carotids and the brain (C/B) and the reins (R), embolisations and endoscopic retrograde cholangiopancreatographies (ERCP). The choice of the procedures was based on their potential impact on the annual exposure of the staff. Thus two main selection criteria were defined: high annual frequency and possible high Kerma Area Product (KAP) values. However, some procedures of low frequency were also considered in the study, in order to include the different parts of the patient body that is irradiated, or because they are often performed in rooms with limited shielding equipment.

b. Measurement protocol

A measurement protocol was established, in order to obtain an accurate description of the staff irradiation scenario and to homogenize the collected data. Thus, different parameters related to the angiographic system, the type and complexity of the procedure, the position of the physician, the protective equipment, the experience of the physician, some field parameters (kVp values, filtration, projections, etc.) and finally the fluoroscopy time, the number of images acquired and the KAP values were recorded.

For the measurements it was decided to use high sensitivity TL dosimeters (LiF:Mg,Cu,P). The TLDs were sealed in small plastic bags and taped on the parts of the body to be monitored. More specifically, 8 TLDs were used, 1 on each ring finger and wrist -on the palmar side when the tube was under the table and on the dorsal side for over couch interventions- 2 on the legs about 5 cm below the lead apron, one between the eyes and one near the left/right eye depending if the tube is on the left/right side of the operator respectively.

c. Results

In figure 1 the average doses at the various dosimetric positions are presented for the three types of categories (IC, IR and ERCP). Among the types of cardiac procedures that were included in the measurement campaign, the doses to the operators are higher during the pacemakers and implantation of cardiac defibrillators (PM/ICD), even though the respective KAP values are relatively low since only fluoroscopy is used. During these procedures the operators work very close to the irradiation field and most of the time without any protective shield.

Among the IR procedures special attention should be given to embolisations, particularly to the doses to the eye lenses. Operators are also significantly exposed during therapeutic procedures such as angioplasties of the lower limbs and the renal arteries. During cerebral and carotid procedures the doses are relatively low since femoral access is usually used and the operator stands at a larger distance from the irradiated part of the patient's body compared to other procedures performed in the thoracic or abdominal region.

Finally, for ERCP procedures the doses are generally low. Special care should be taken regarding the use of a ceiling suspended shield, especially for the protection of the eyes, when overcouch irradiation is used.

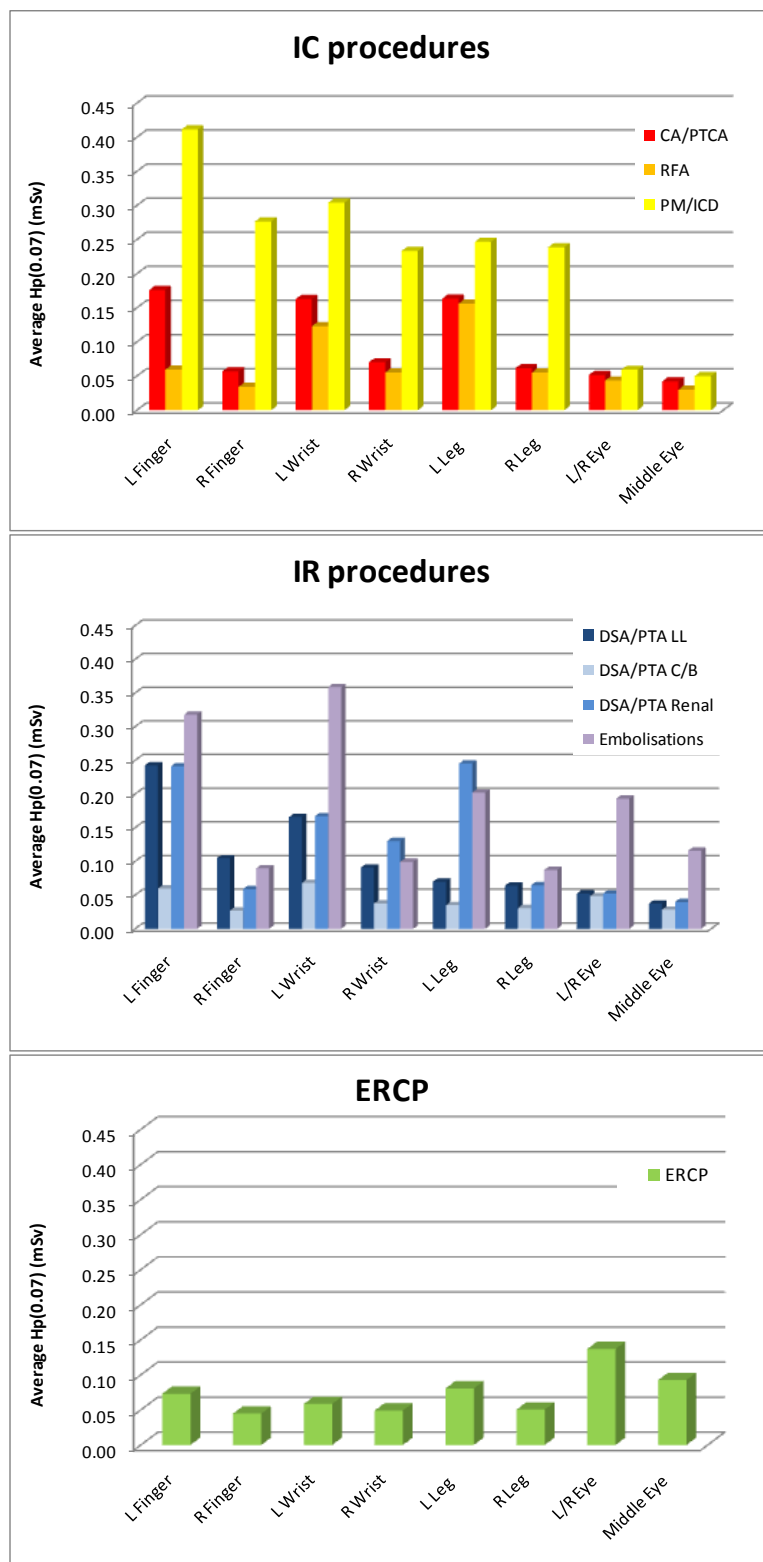


Figure 1: Mean doses per type of examination separated into 3 categories (IC, IR and ERCP).

The position of the maximum dose was found to be at the part of the operator which is close to the X-ray tube. Figure 2a shows an example of the frequency of this position for embolisation procedures. More generally, in all the procedures studied the left wrist was found to be the position

where the maximum dose was recorded most often, followed by the left finger. The maximum was found generally at the left wrist for femoral access and at the left finger for radial or direct access, the operator being then closer to the beam field. Therefore, both wrist and ring dosimeters are suitable for the routine monitoring. However, taking into account the respective annual limits for all positions (150 mSv for the eyes and 500 mSv for the extremities) the eye lens exposure is more important (see figure 2b for embolisation procedures).

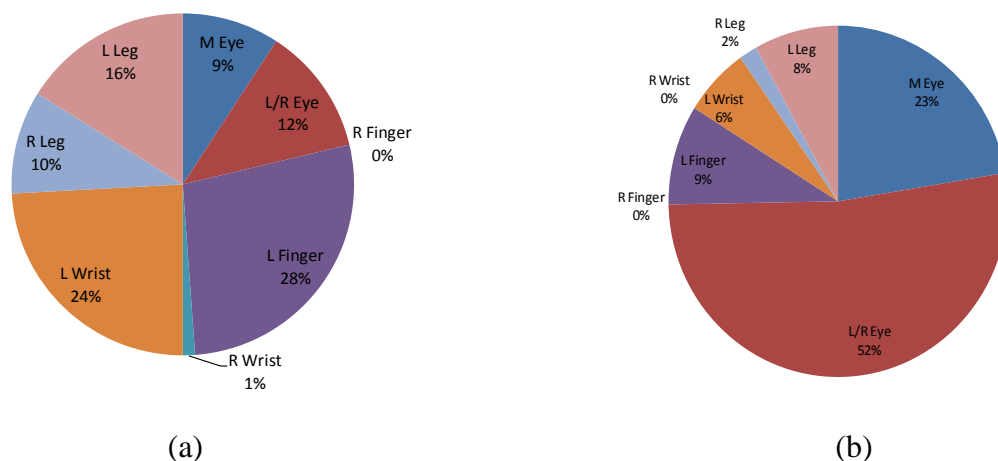


Figure 2 (a): Frequency of the position of the maximum dose in embolisation procedures. **(b):** Frequency of the position of the maximum dose in embolisation procedures when the respective annual dose limits are taken into account

According to the information on the annual workload that was gathered from 84 physicians, the annual limit for the skin on the fingers could be exceeded only for a few workers but the annual doses were estimated based only on the procedures for which the operator was monitored during the measurement campaign.

In the case of the CA/PTCA procedures, 5 to 15% of the workers seem possible to receive an annual dose above the 3/10th of the annual limit. Furthermore, there are around 5% of the workers that could even exceed the annual skin effective dose of 500 mSv for PM/ICD procedures. Thus, the monitoring of the hands is definitely a requirement for interventional procedures especially in interventional cardiology. The annual doses were considered low for the ERCP procedures, so the monitoring of the hands is not necessary in this case.

Although the annual doses to the legs can be high for certain kind of procedures (e.g. DSA PTA renal), it was shown within the analysis performed in WP1 that this was mainly happening for tube-below couch configurations without any shield attached to the operating table. Therefore, the monitoring of the doses to the legs is not needed when a table shield is properly used.

Finally, the eye lens doses can be high so monitoring is also recommended for all investigated procedures, except ERCP. Especially, if the dose limit for the eye is decreased in the future, monitoring and protection measures will be even more important.

2. Simulations

a. Description of the input file

The numerical simulations have been performed using the MCNP-X code. The MIRD type anthropomorphic models have been used for the simulation of the patient and the operator. The “patient” phantom is at supine position, and the “operator” one is standing close to it, in a configuration that is typical in an IR and IC procedure. The original model was modified in order to

represent more realistically the irradiation scenario: eyes have been added, the arms have been redefined and forearms and hands are bent in a more realistic position. A thyroid collar of 0.5 mm Pb and a lead apron of 0.5 mm Pb in front of the body have also been added. Finally, a cell filled with air representing the KAP chamber and the image intensifier (II) have been added to the input file.

F6 tallies were used for the calculation of the doses to the eye lenses, hands, wrists and legs. The tallies were positioned at 0.07 mm and at 3 mm depth for the calculation of $H_p(0.07)$ and $H_p(3)$ respectively.

b. Geometry characteristics

The X-ray tube was simplified to a point source emitting a photon beam in a cone with an aperture corresponding to that desired for the simulation of the X-ray field diameter. The energy spectra for the selected kVp and filtrations were determined using the X-ray data of the Institute of Physics and Engineering in Medicine (IPEM), Report 78. Moreover, the lead collimator was not simulated explicitly, but defined as a volume killing all the photons (not further simulated) entering inside it.

The first parameters examined within the simulation campaign are the tube voltage and the filtration. More specifically, the tube voltage was changed from 60 to 110 kVp, and the filtrations from 3 to 6 mm Al and from 0 to 0.9 mm Cu. Moreover, simulations also were performed for the following cases:

- Beam projections: Posterior Anterior (PA), Left Anterior Oblique (LAO) and Right Anterior Oblique (RAO) at angles of 30°, 60° and, 90°, Caudal (CAU) and Cranial (CRA) projections at 20° and 40° and several combinations of these observed in clinical practice.
- Field size at the II: diameter from 10 to 40 cm, depending on the part of the body that is considered to be irradiated
- Different positions of the operator (representing femoral, or radial access)
- Protective glasses for the operator: no glasses, lead glasses of 0.5 mm and 1 mm Pb equivalent thickness
- Protective equipment for the room: combination of the three lead barriers: table curtain, patient shield and ceiling shield
- 4 parts of the body irradiated: head and neck, thorax, abdomen/pelvis and lower limbs.

c. Results

The beam projections for which the operator is the most exposed are the left anterior oblique (LAO), where the operator stands at the side of the X-ray tube, and the cranial projections, where the image intensifier is towards the patient's head. When comparing the overcouch (AP) with undercouch (PA) irradiations, the doses are found significantly lower for the undercouch one, up to 12 times for the eyes, 8 times for the hands and 4 times to the wrists, for the selected geometries. In case of PA the dose to the legs (in particular the left) can be relevant if no table shield is used. For the lateral projections, the RAO 90° should be preferred (operator standing at the side of the image intensifier), as the doses were found lower compared to the LAO 90°, up to 3 times for the eyes, 3 times for the hands and 22 times for the wrists, for the selected geometries.

The table shield is very effective for the protection of the legs and reduces the dose from 83% to 99% for the geometries and setups that were tested. The lead glasses, for the specific geometry that was examined, are very effective for the protection of the eye lens which is closer to the X-ray tube (dose reduction up to 90%). In practice, lead glasses that cover well the eyes and also have lateral protection are advised. Lens thickness of more than 0.5 mm Pb doesn't improve the protection of the eye lenses significantly.

A ceiling suspended shield is also very effective for the protection of the eye lenses; its use is essential especially when lead glasses are not available or cannot be worn for practical reasons, and when overcouch irradiation is used. This type of shield also provides protection to the hands (up to

68%) and wrists (up to 73%). The simulations showed how important it is to correctly place the ceiling shield. Even a small gap between the patient and the shield reduces the effectiveness of the shield to the hands. For this reason a shield with lead stripes attached at the bottom so that it touches the patient is advised. For the lateral projections the eyes are better protected when the shield is positioned closer to the side of the operator and not just above the patient. In practice, a second shield is advised especially when biplane systems are used, so that the operator is protected from both X-ray tubes.

For all monitored positions the doses are higher when larger field sizes are used. The largest dose increase is observed to the left hand which is closest to the irradiation field. The dose reduction to the hands and wrists because of a more collimated beam becomes much more important when the operator stands closer to the irradiation field. The dose to the legs and eye lenses seem to be the less affected by the beam collimation.

Concerning the beam quality, more energetic beams lead to lower doses to the operator up to 60%. However, one should keep in mind the deterioration of image quality and contrast in this case.

3. Recommendations

The measurement and simulation campaign performed within the ORAMED project revealed a large variability of practices followed in different hospitals. As a consequence, the measured doses, even for specific procedures, vary significantly from one case to another. On the other hand, the simulation data showed the way that each parameter separately can influence the extremity and eye lens doses and not in combinations as it is the case from the measurement results. The combined data led to the following recommendations. It is important to note that some of the proposed guidelines cannot easily be adopted since there are restrictions from the medical point of view. However, some of them are easily adjustable and can improve the protection of the medical staff significantly.

- The equipment used for interventional cardiology and radiology should fulfill specific requirements and standardisation in their design, manufacture, acceptance and maintenance.
- Personal protective equipment should be used for all the personnel in the room (at least lead collar and aprons). For the protection of the eyes see the following recommendations.
- The ceiling suspended shield should be placed just above the patient, especially in the cases that the tube is above the operating table; the operator should stand well behind it. The combination of transparent ceiling shield and lead drapes that touch the patient is very efficient for the protection of the hands. When the ceiling shield is properly used there is a significant reduction of the eye dose (2-7 times), especially in cases where the tube is placed above the operating table.
- When ceiling suspended shield is not available or cannot be used for practical reasons protective lead glasses should be used; most effective are the ones designed with large area lenses, well covering the eyes, and with the lateral shadow.
- The table shield should be always properly adjusted to protect both legs. The proper positioning of the table shield is very important also for the assistant operator, who, in many cases, stands close to the main operator but his legs are not protected. There are also cases where the operator needs to change his position during the procedure, and stands close to the table without having his legs protected anymore. The proper use of table shield can reduce the leg doses from 2 to 5 times.
- The tube should be placed below the operating table when C-arm systems are used. As compared with an overcouch configuration, there is a significant reduction to the eye (2-27 times) and hand doses (2-50 times). However, the increase at the leg doses for this setup has to be compensated by the use of a properly positioned table shield.

- If biplane systems are used, the proper use of lateral shield is very important for the protection of the eyes. It is more effective if the shield is positioned at the side of the operator (or next to the operator).
- Mobile floor shield should be used for the assisting personnel that need to be in the irradiation room.
- The femoral access of the catheter should be preferred, if it is possible from the medical point of view, compared to the radial one (as long as it is associated with a larger distance from the beam field than when radial access is applied). The extremity and eye lens doses, if the shields are properly used, are lower for femoral access, by 2 to 7 times.
- The use of an automatic image injector which allows the operator to leave the room during the image acquisitions is a practice which can reduce the doses significantly (4 to 16 times), especially to the hands.
- The operators should avoid direct exposure of hands to primary radiation.
- Monitoring of the eyes and fingers (or wrists) should be performed on routine basis. The dosimeters should be worn on the side of the operator which is closest to the X-ray tube. The finger (or wrist) dosimeter should be placed on the dorsal or palmar side of the hand when the X-ray tube is placed above or below the operating table, respectively.

WP2: Development of practical eye lens dosimetry

1. Discussion on $H_p(3)$ and related Monte Carlo studies

The basic step of WP2 was to revise the approach for the definition and calculation of conversion coefficients for $H_p(3)$. Relying on morphological studies on the head, it was decided to propose a cylindrical (20 cm diameter and 20 cm height) simplified 4-element tissue equivalent phantom on which to calculate the operational quantity.

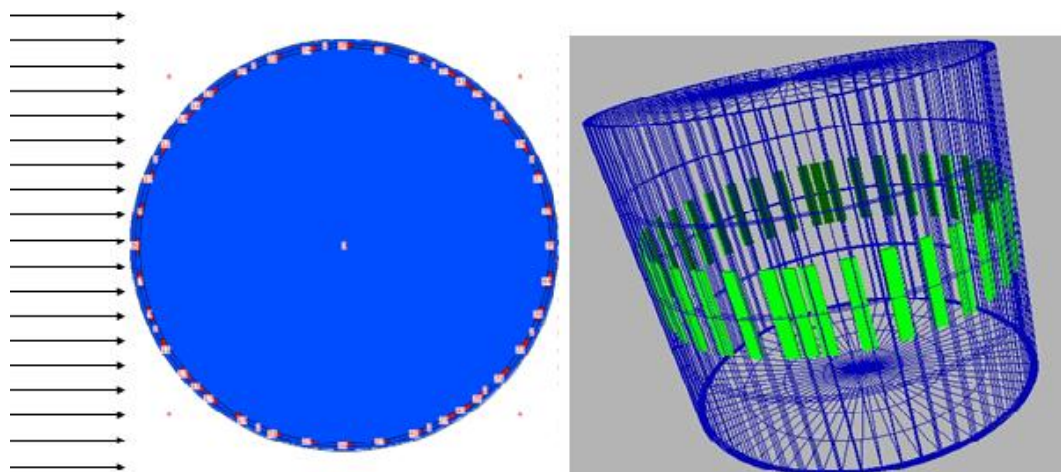


Figure 3: The irradiation model to calculate $H_p(3, \alpha)$ values

The discussion was especially motivated by the fact that the possible adoption of the trunk phantom (30x30x15 cm³) also for calculating $H_p(3)$ seemed to be rather inappropriate due to its strong deviation from the reality in terms of mass and shape. In particular the 30x30cm² plane face is too large and of different shape than the head. Moreover, the edges play a very important role when looking at the angular dependence of the operational quantity. Such effects also influence the calibration procedure, if such phantom is adopted in the procedure, as its backscatter characteristics are not corresponding to what happens in practice to a target organ like the eye embedded in the head

(and not in the trunk). The geometry model adopted is shown in Figure 3. It shows that the cylindrical symmetry allows to obtain, for a given energy, all the $H_p(3,a)$ values for all the possible irradiation angles in a single Monte Carlo run.

In this way a new set of photon conversion coefficients from air kerma K_a to $H_p(3, \alpha)$ were obtained (Figure 4 for normal incidence). The Figure shows the failure of the kerma approximation for photon energies above 1 MeV (3mm is the range in tissue of 800 keV secondary electrons).

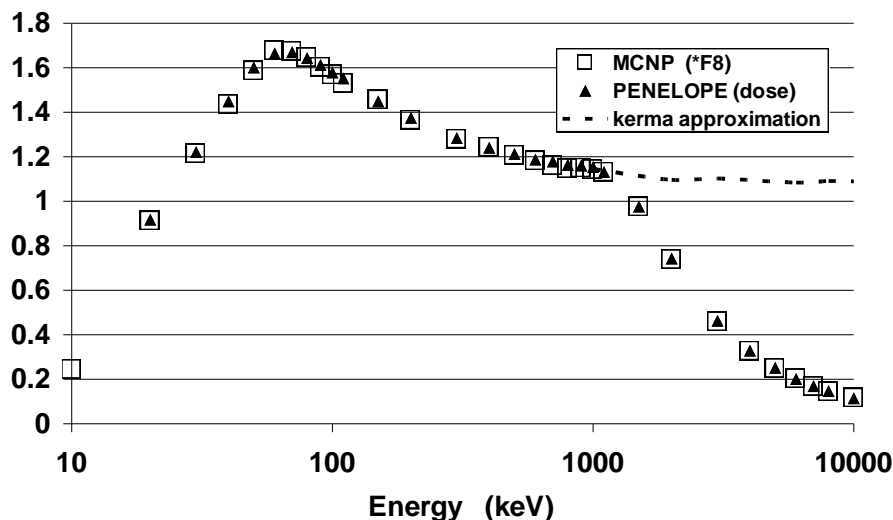


Figure 4: $H_p(3, 0^\circ)/K_a$ evaluated with MCNPX and PENELOPE. Above 1 MeV the secondary electron transport has to be taken into account.

The calculations demonstrated the better suitability of the adoption of the cylinder to reproduce the organ equivalent dose (eye lens) in various irradiation conditions.

It has to be pointed out that, as expected the operational quantity as determined on the proposed cylinder are in satisfactory agreement with the limiting quantity. Moreover it should be noted that for nearly grazing incidence that could occur in IR/IC procedures, in which the patient acts as a scattering object, the operational quantity as determined in the trunk slab is not conservative estimate of $H_T(\text{eye lens})$. The present general considerations justify the adoption of the new phantom to develop a self-consistent eye lens dosimetry procedure. It has to be pointed out that the new calculated operational quantity $H_p(3,\alpha)$ based on the cylinder is also better fitting (compared with the values based on the trunk slab phantom) with the $H_T(\text{eye lens})$ values actually reported in ICRP-74 and ICRU-57.

2. RADCARD Dosemeter prototype

On the basis of the studies on $H_p(3)$ and the new set of conversion coefficients produced, a prototype (shown in Figure 5) was developed by RADCARD with the support of ENEA and CEA. The dosimeter had to satisfy the following conditions: 1-measuring correctly $H_p(3)$ for eye-lens, 2- being comfortable for users and for dosimetric services, 3-waterproof, and 4- inexpensive

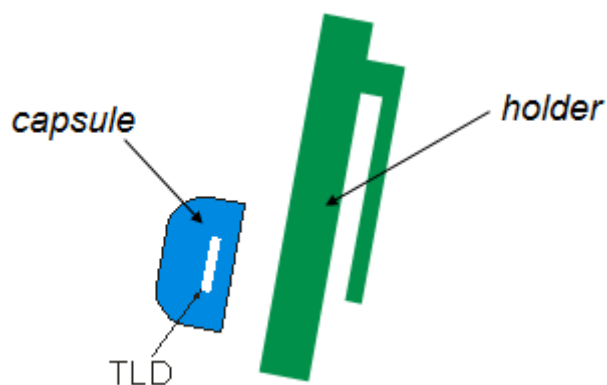


Figure 5: A sketch of the dosimeter's elements

The characteristics to be optimized were the energy response and the angular response. The study was performed mainly using MCNP simulation varying the TLD detector type and dimension ; the capsule material and dimension.

For the capsule, various materials were investigated like PMMA, polyurethane, polystyrene, polyamide, polyethylene, PVC and PTFE.

The employed tools for the optimization were Monte Carlo simulations of coupled photons and secondary electrons and irradiations using X-ray beams on phantom. The adopted model describes the dosimeter mounted on the cylindrical calibration phantom and the parametric study was performed in order to obtain an energy response as closer as possible to $H_p(3)$.

To reproduce the reading of the TLD, the energy deposition Monte Carlo estimation was folded with the light emission efficiency for secondary electrons as evaluated at Institute of Nuclear Physics in Krakow some years ago.

The experimental irradiations were carried out using beams from the RQR and Narrow Series (Figure 6). The first series, with a moderate filtration better reproduce the operative condition met in IR/IC, whilst the second, with high filtration is closer to mono-energetic photons.

X-ray spectra: IEC RQR series, ISO narrow N series

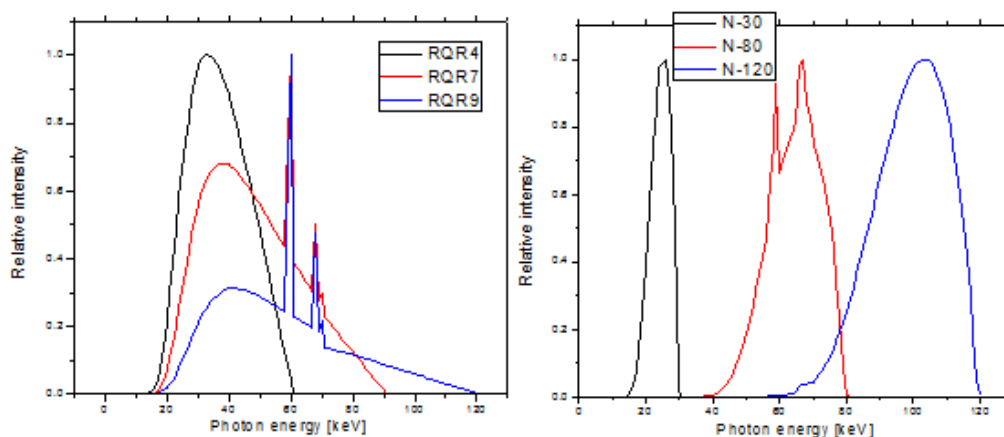


Figure 6: X-ray beams spectra employed for the irradiations

The prototype (Figure 7) was finally tested at the CEA-LNE Laboratories in Saclay (France) and the irradiation results were compared with Monte Carlo simulations. The calculations were performed with the Narrow Spectrum Series. The results (Figure 8) are in a very satisfactory agreement.

Steps of dosimeter development:

1. Working model: only capsule, technology: cutting



2. Pre-prototype:



3. Final prototype

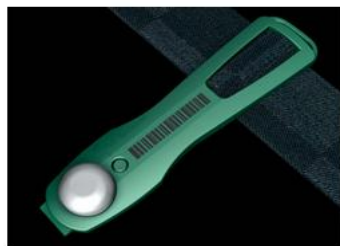


Figure 7: The three steps towards the prototype construction

Moreover it should be pointed out that the energy response of the dosimeter presents a variation of $\pm 20\%$ (Figure 8) whilst the angular dependence is well fitting the theoretical behaviour within $\pm 10\%$ (Figure 9). The dosimeter optimized design allows a good quality measurement of the eye lens dose equivalent-

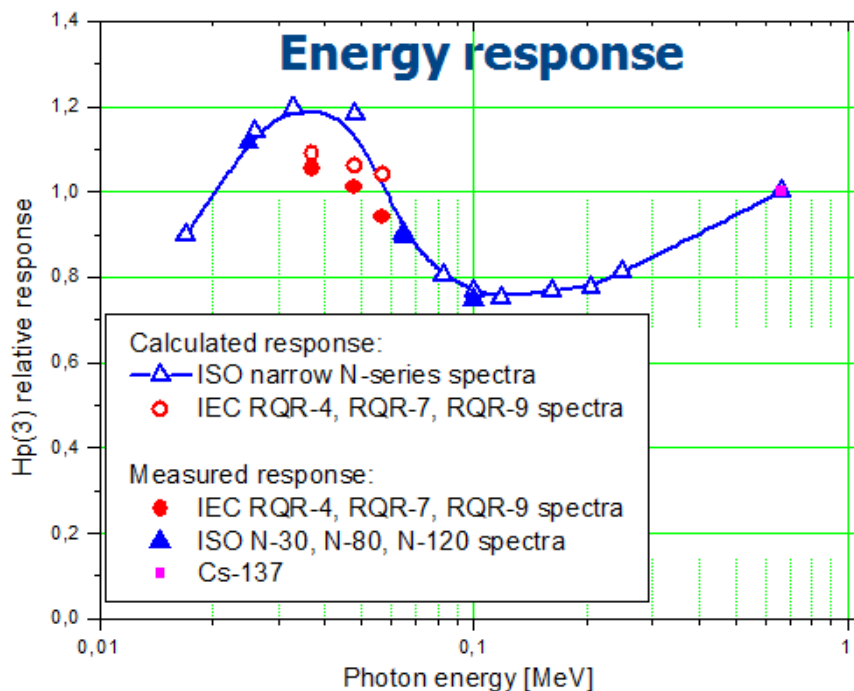


Figure 8: Numerical and experimental energy response

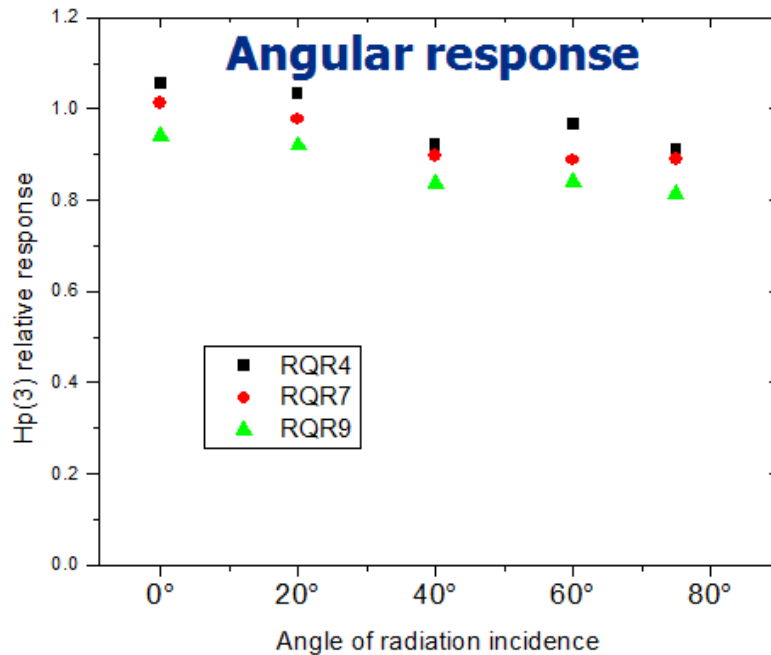


Figure 9: Experimental angular response

3. Establishing a Protocol for type test and calibration of personal dosimeters in terms of $H_p(3)$

This part of the work was aimed at making a proposal for the type test and calibration of eye lens passive dosimeters especially designed to be used in interventional radiology/cardiology. Starting from the only one existing standard dealing with eye lens dosimetry using TLDs (ISO 12794), parameters such as, detection threshold, energy and angle responses have been reviewed and have been harmonised, as much as possible, with the IEC 62387 requirements, taking into account the particular use at IC/IR workplaces. Conversion coefficients from air kerma to dose equivalent at 3 mm depth for RQR and ISO radiation qualities, employed for type test and calibration purposes, have been calculated in the new phantom introduced by ORAMED (Figure 3).

Type tests are intended to demonstrate that the dosimeters are suitable for measurements in workplace conditions. For dosimetry systems based on passive personal dosimeters, two international standards covering photon and beta radiations exist for type testing: IEC 62387-1 and ISO 12794. Table 1 presents the main features of these standards. A few remarks can be done about their main contents: (i) even if the goal of these standards is the same, two slightly different approaches are used. ISO standard requirements are based only on the characteristics of the dosimeter responses while IEC standard includes separate requirements for the reader, the ancillary equipments and the procedures for converting the reading to dose; (ii) only the ISO standard takes into account the eye lens dosimetry; (iii) ISO standard is especially written for thermoluminescent detectors based dosimeters (TLD) while IEC standard includes any type of passive dosimeters; (iv) none of these standards take into account the pulsed radiation fields; (v) these standards do not address the same type of dosimeters, so that they cannot be fully harmonized and the comparison between the test results require exhaustive analysis. For the above reasons, it is more suitable to start from the ISO standard to make proposals for passive dosimeters for eye lens monitoring. As it is mentioned, in the introduction of ISO 12794, this international standard should be used in conjunction with IEC 61066 (which has been replaced by IEC 62387-1) to look at additional

requirements relative to additivity and to the reader (electromagnetic compatibility, mechanics and software) which could be added later on the basis of IEC standards.

Table 1: Comparison of the main requirements of ISO and IEC standards for passive photon dosimetry (adapted from IEC 62387-1, ISO 12794 and EC report 160).

| (Influence) quantity | This work (proposal) | ISO 12794 | IEC 62387-1 | |
|-------------------------------------|--|--|--|---|
| | All passive Eye lens | TLD, Extremity and Eye lens $H_p(0.07)$ and $H_p(10)$ | All passive $H_p(0.07)$ | All passive; $H_p(10)$ |
| Radiation energy | (15 keV to 3 MeV) $0.6 \leq \text{response} \leq 1.4$ (20 keV to 100 keV) $0.7 \leq \text{response} \leq 1.3$ | (15 keV to 3 MeV) $0.5 \leq \text{response} \leq 1.5$ | Energy 30 keV to 250 keV and angle: $0.71 \leq \text{response} \leq 1.67$ | Energy 80 keV to 1.25 MeV and angle: $0.71 \leq \text{response} \leq 1.67$ |
| Angle of incidence (0 to 60°) | $0.85 \leq \text{response} \leq 1.15$ (0° to 60°) $0.7 \leq \text{response} \leq 1.3$ (0° to 75°) | at 60 ± 5 keV: $0.85 \leq \text{response} \leq 1.15$ | | |
| Threshold | 0.2 mSv | 1 mSv | 0.01 mSv (from the “scope and objet” chapter) | |
| Linearity | 0.2 mSv to 1 Sv $0.9 \leq \text{response} \leq 1.1$ | 1 mSv to 1 Sv: $0.9 \leq \text{response} \leq 1.1$ | 1 mSv to 3 Sv $0.91 \leq \text{response} \leq 1.11$ | 0.1 mSv to 1 Sv $0.91 \leq \text{response} \leq 1.11$ |
| Coefficient of Variation | Criteria from both IEC and ISO standard are relevant | reproducibility: 10% batch homogeneity: 15% | from 15% (< 1 mSv) to 5% (≥ 11 mSv) | from 15% (< 0.1 mSv) to 5% (≥ 1.1 mSv) |
| Environmental conditions and others | | temperature up to +40°C and humidity up to 90%: $0.9 \leq \text{response} \leq 1.1$ light exposure: $0.9 \leq \text{response} \leq 1.1$ | temp.: -10°C to +40°C, humidity 40% to 90%, fading, light, reader stability and power supply combined: $0.83 \leq \text{response} \leq 1.25$ | |
| Additivity (1) | Not treated in this paper | no requirement | $0.91 \leq \text{response} \leq 1.11$ | |
| Electromagnetic Compatibility (EMC) | | | IEC 61000-6-2 deviation (2) limited | |
| Mechanics | | | IEC 60068-2-32 ; deviation (2) limited | |
| Software | | | WELMEC Guide 7.2 (3) | |

(1) Additivity of measured values for different irradiation conditions.

(2) Deviation is an additional indication which is due to the influence quantity, e.g. to additional or lost pulses as a result of EMC.

(3) A guide to software requirements from the European Corporation in Legal Metrology, recommended for application all over Europe.

The comprehensive document treats the following aspects:

- Wearing conditions at the IR/IC workplaces and consequences on type test criteria
- Detection threshold
- Performance requirements for energy response
- Performance requirements for angle response
- Other requirements
- Calibration

Table 2 reports the characteristics of radiation fields from CONRAD Project (ref.), ISO 4037 and IEC 61287 and the conversion coefficients $H_p(3) / K_a$ (Sv/Gy) for some RQR, Wide-ISO and Narrow-ISO suited for the range of energies of interest to be used in the calibration process.

Table 2: Conversion coefficient $H_p(3) / K_a$ (Sv/Gy) from air kerma to dose equivalent at 3 mm depth in the square right cylindrical phantom. Monte Carlo calculations with PENELOPE, standard uncertainties less than 0.3%

| Angle (degree) | RQR4 | RQR7 | RQR9 | W 60 | W 80 | W 110 | W 150 | N30 | N80 | N120 | Conrad Primary beam 70 kV |
|----------------|-------|-------|-------|------|------|-------|-------|-------|-------|-------|---------------------------|
| 0 | 1.239 | 1.376 | 1.461 | 1.47 | 1.58 | 1.65 | 1.57 | 1.019 | 1.665 | 1.588 | 1.495 |
| 20 | 1.229 | 1.373 | 1.452 | 1.46 | 1.58 | 1.63 | 1.54 | 1.009 | 1.659 | 1.584 | 1.484 |
| 45 | 1.179 | 1.326 | 1.406 | 1.42 | 1.53 | 1.60 | 1.54 | 0.955 | 1.599 | 1.554 | 1.429 |
| 60 | 1.108 | 1.253 | 1.347 | 1.34 | 1.47 | 1.54 | 1.50 | 0.875 | 1.546 | 1.516 | 1.367 |
| 75 | 0.953 | 1.107 | 1.210 | 1.20 | 1.34 | 1.45 | 1.40 | 0.698 | 1.420 | 1.424 | 1.231 |
| 90 | 0.599 | 0.768 | 0.884 | 0.87 | 1.02 | 1.15 | 1.17 | 0.336 | 1.118 | 1.167 | 0.900 |

CONCLUSIONS

WP2 of the ORAMED project allowed establishing a new and self-consistent approach for an improved dosimetry procedure on the eye lens. Starting from the proposal of a well suited simple phantom for the theoretical quantity, the corresponding designed calibration phantom was fabricated at a very low cost. Thereafter the phantom was adopted during the ORAMED project for calibrations of the prototype. It was developed to respond in the best way in terms of $H_p(3)$, according to the protocol that was conceived to offer clear guidelines specifically addressed to the eye lens personal dosimetry. The obtained results can be of help to the dosimetry community working in the medical field and also in other disciplines.

WP3: Optimization of the use of active personal dosimeters in interventional radiology and cardiology

1. Tests of eight commercial APDs in laboratory conditions with continuous and pulsed X-ray beams and in hospitals

a. Selection of APDs

The following APDs were selected for the current study (Figure 10), according to their capability to detect low energy photons: DMC2000XB (MGPI), EPDMk2.3 (Siemens), EDMIII (Panasonic), PM1621A (Polimaster), DIS-100 (Rados), EDD30 (Unfors), AT3509C (Atomtex) and DoseAware (Philips).



Figure 10: Active personal dosimeters tested in this study

b. Tests of APDs with continuous X-ray beams

Material and methods

The tests with continuous X-ray fields were made in two calibration laboratories (IRSN in France and SCK•CEN in Belgium). These tests were performed to determine the response of selected APDs in terms of personal dose equivalent, energy, personal dose equivalent rate and angle. The following reference fields were used (N-15, N-20, N-25, N-30, N-40, N-60, N-80, N-100, N-120, S-Cs and S-Co) as defined in the ISO 4037-1 standard (International Organization for Standardization, 1996). Three measurements per APD were performed. Two dosimeters of each type were tested.

Dosemeters were placed on an ISO slab phantom (International Organization for Standardization, 1999). The results were analysed considering the requirements of the IEC 61526 standard.

Results

The personal dose equivalent response of the tested APDs is linear in the dose range of interest in radiation protection, i.e. up to 500 mSv. The energy response of the tested APDs is within the interval [0.71 – 1.67] as required in the IEC 61526 standard (International Electro technical Commission, 2010), from S-Co energy down to N-30 for all APDs except EDD30 and DoseAware. EDD30 energy response is within the IEC requirements between N-80 and N-20 qualities; dose Aware energy response is within requirements between N-120 and N-40.. Most APDs can stand high dose rates up to 10 Sv.h⁻¹, except PM1621A, for which the response diverges rapidly from 1 Sv.h⁻¹, as well as EDD30 and DoseAware which saturate for personal dose equivalent rates above 2 and 4 Sv.h⁻¹ respectively. It is interesting to notice that most APDs can stand personal dose equivalent rates higher than those indicated in their technical note. The angular response is within the interval [0.71 – 1.67] (International Electro technical Commission, 2010) for energies down to N-30 for all APDs, apart from AT 3509C for which the angular response is inside the before mentioned interval at 60° only for N-80.

c. Tests of APDs with pulsed X-ray beams

Material and methods

The tests in pulsed mode were performed at the French standard laboratory for ionizing radiation (Laboratoire National Henri Becquerel, CEA-LIST LNE-LNHB in France). The influence of several parameters in different conditions (Table 3) on the response of the APD in pulsed mode was studied.

Table 3: Parameters used for the tests performed in pulsed radiation field (70 kVp, 4.5 mmAl + 0.2 mmCu, HVL 5.17 mmAl)

| Test | Pulse duration (ms)* | Pulse frequency (s ⁻¹) | Personal dose equivalent rate (Sv.h ⁻¹) |
|---|----------------------|--|---|
| Effect of personal dose equivalent rate | 20 | 10 | 0.1 to 50 (up to 1.8 for DoseAware) |
| Effect of pulse frequency | 20 | 1, 10 and 20 (1 and 10 for DoseAware) | 1.8 to 6.8 (0.9 and 1.8 for DoseAware) |
| Effect of pulse width | 20 to 1000 | Single pulse mode | 1.8 |

Results

For most APDs, the response decreases when the personal dose equivalent rate increases (Figure 11). For personal dose equivalent rates lower than 2 Sv.h⁻¹, the responses are, in general, close to 1 and fall down more or less rapidly for higher dose rates, except DIS-100 that gives a correct response up to 55 Sv.h⁻¹. It was noticed that PM1621A, equipped with a Geiger-Muller tube, does not provide any signal at all in pulsed mode. DMC 2000XB, EPD Mk2.3, EDMIII, EDD30, AT3509C and DoseAware contain all silicon detectors. The difference of their response to the pulsed mode is probably due to the time response of their electronic systems. DIS-100, which has a “hybrid” technology between silicon and ionisation chamber, presents correct results.

The variation of the APD response with the pulse frequency between 1 and 20 s⁻¹ is roughly equal to 10% for EDMIII, EDD30 and DoseAware and to 30% for the other devices (except PM1621A that does not provide any signal in pulsed mode).

When the pulse width is larger than 1 s, the responses in pulsed and continuous radiation field are quite similar. No significant effect of pulse width was observed on the response of all APDs. All results from the pulsed field tests show that the longer the pulses and the higher the frequency, the better the behaviour of the devices tends to be.

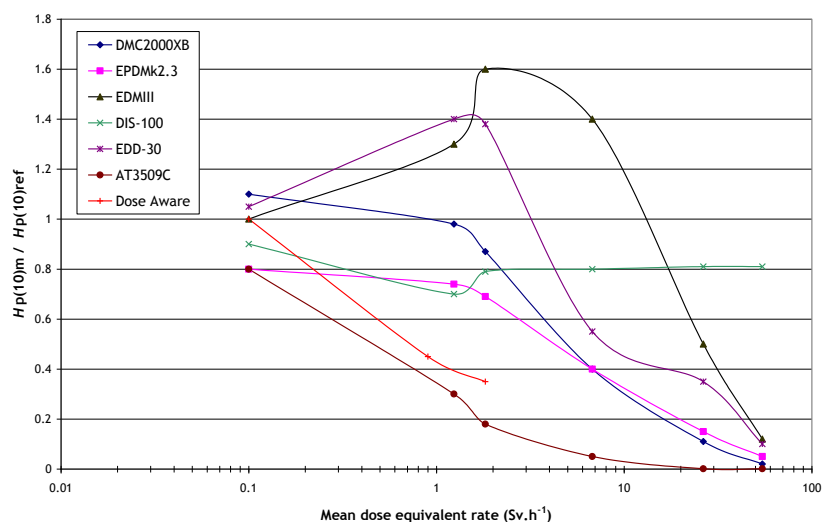


Figure 11: Personal dose equivalent rate response of APDs in pulsed mode for a pulse frequency equal to 10 s^{-1} and a pulse duration of 20 ms

d. Tests in hospitals

1) Tests on phantoms

Material and methods

The first series of tests in real conditions were performed by positioning APDs on an ISO slab phantom representing the operator. The scattered irradiation was produced by an anthropomorphic Rando-Alderson phantom representing the patient. The tests were performed on a X-ray system (PHILIPS BZR79 Optimus). The APDs tested were: DMC 2000XB (MGPI), EPD Mk2.3 (Siemens), EDM III (Dosilab), PM1621A (Polimaster), DIS-100 (Rados) and EDD30 (Unfors).

As reference the routine passive thermoluminescence dosimeter (TLD) from the Belgian Nuclear Research Centre was used (uncertainty 20%). Both the APD as the TLD were positioned together on the ISO slab phantom. The dose uniformity on the surface of the phantom was within 20%. The thorax of the RA-phantom was irradiated and different realistic set-ups were considered. The main objective of these tests was the study of the behaviour of the APDs in realistic conditions with the possibility to select specific field parameters.

Results

In a range of dose equivalent rates tested from 10 mSv.h^{-1} to 1.8 Sv.h^{-1} , the APD response is within 50% for the range of dose equivalent rates tested, except for the EDM III for which the dose is general higher than the TLD dose and except PM1621A that does not give any signal, which is consistent with the laboratory tests in pulsed fields. No important influence of the tube voltage and of the pulse width was observed on the APD response compared to the TLD.

2) Tests on operators

Material and methods

For these series of tests operators wore, side by side, one APD and one passive dosimeter above the lead apron. The dosimeters were worn during several interventions to integrate doses of at least $300 \mu\text{Sv}$ for several types of IR/IC procedures. The dose equivalent was provided by the passive dosimeter according to the routine measurement protocol of the respective partner that performed the measurements. For practical reasons only 5 APD types were tested: DMC 2000XB (MGPI), EPD Mk2.3 (Siemens), EDM III (Dosilab), DIS-100 (Rados) and DoseAware (Philips). In total 102 measurements were performed in 7 different European hospitals. The main objective was to compare

the measurements performed by the APD and passive dosimeter worn in routine practice where all kinds of procedures and parameter settings are used and without an accurate knowledge of these parameters.

Results

With respect to passive dosimeters, in general all 5 tested APDs under-respond (Figure 12). We can observe a large spread in the results, which might be explained by non-uniform irradiations or the shielding of one dosimeter by the other.

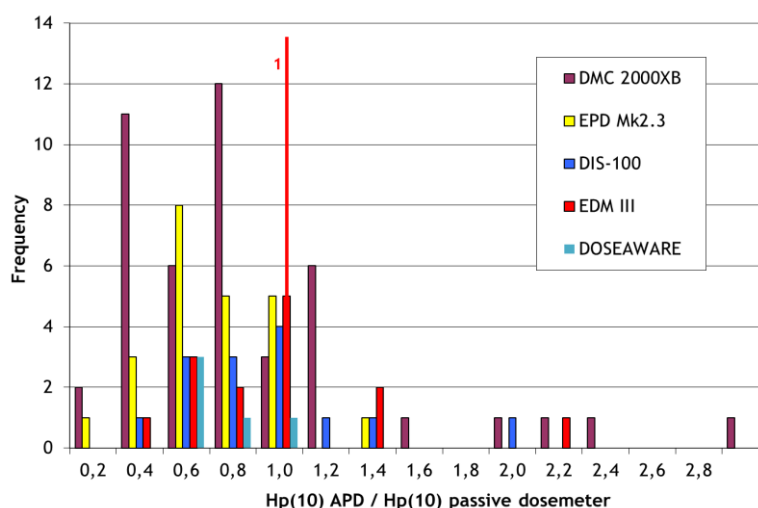


Figure 12: Frequency distribution of the APD response related to the passive TLD in routine practice

2. Guidelines for the use of APDs in interventional radiology, one with the input of above mentioned laboratory tests and tests in hospitals

Some recommendations were prepared within the group to help in selection and use of APDs at IR/IC workplaces. These recommendations are compiled on a three page leaflet available on the ORAMED website <http://www.oramed-fp7.eu/>.

a. Recommendations for the selection of an APD in IR/IC

- The APD has to fulfill the requirements of the IEC 61526 standard, and, in particular, the following specific points.
 - The energy response has to be within the interval [0.71 – 1.67] for the energy range 20 – 100 keV.
 - The angular response has to be within the interval [0.71 – 1.67] for angles from 0° to 60° from reference direction and for the energy range 20 - 100 keV.
 - The maximum dose equivalent rate required by the IEC 61526 standard is 1 Sv.h⁻¹ but, since dose equivalent rates can be high when standing very close to the direct beam, if the APD can stand higher dose equivalent rates it should be taken into account as a positive characteristic. In any case, the APD should be able to give at least an alarm for dose equivalent rates higher than 1 Sv.h⁻¹.
- As pulsed radiation fields are not taken into account in existing standards, some information on the APD characteristics in pulsed field similar to those met at workplace is needed (i.e. effect of pulse frequency and width on the dose equivalent response). Different sources of information can be used such as the results of the tests performed within the ORAMED project or those eventually performed by the manufacturer. It is also possible to perform his/her own tests using ISO slab phantoms to simulate the patient and the operator and placing the APD and a passive

dosemeter side by side. It is recommended to integrate at least 300 μSv for a typical configuration. A factor of 2 between the doses given by the two types of dosimeters can be considered acceptable.

b. Recommendations for the use of an APD in IR/IC

- An APD has to be periodically (according to local regulation) calibrated or verified in terms of $H_p(10)$ with X-ray beams in a calibration laboratory traceable to a primary standard, the conditions of calibration have to be as close as possible to those of use.
- An APD should be considered, in this application in IR/IC, as a tool to optimize and reduce the exposure, it is thus recommended to wear it over the lead apron.
- It is not recommended to use APD for the legal dose record in case of IR/IC, the reference $H_p(10)$ value should be given by the passive dosimeter. Passive dosimeters are technically better suited to measure the radiation fields in IR/IC
- The alarm should be switched ON (only visual alarm) in order to warn the operator when he/she is too close to the direct beam. The value to which the dose rate alarm shall be set depends on the characteristics of both the pulsed radiation field and the APD.

3. Development of a prototype of an improved APD for interventional radiology by MGPIstruments.

The objective was to propose technical solutions to improve the response of an APD for an application in IR/IC based on the results of the tests in laboratory conditions. The different technical solutions (with continuous feedback) developed by MIRION Technologies during this period were tested in laboratories. A prototype called was developed.

The first improvement on the prototype consisted in having a good energy response. By selecting the materials in front of the detector (shape and composition) and adjusting the energy thresholds of the discriminators, it has been possible to reduce down to $\pm 10\%$ the deviation of the response all over the 20-100keV energy range used in IR/IC procedures (Figure 13).

The second task was to reduce the angle influence on the dosimeter response. The position of the two detectors and the shape of the detection module have been re-designed in order to have a good isotropy for angles of irradiation greater than $\pm 60^\circ$. The angular response is now within a $\pm 30\%$ deviation for angles up to $\pm 65^\circ$ all over the 20-100 keV energy range.

In addition, a study of the dead time compensation was conducted in order to reach dose rates as high as 10 Sv.h^{-1} . The response is now better than $\pm 20\%$ up to 10 Sv.h^{-1} in continuous mode and $\pm 20\%$ up to 20 Sv.h^{-1} in pulsed mode (Figure 14).

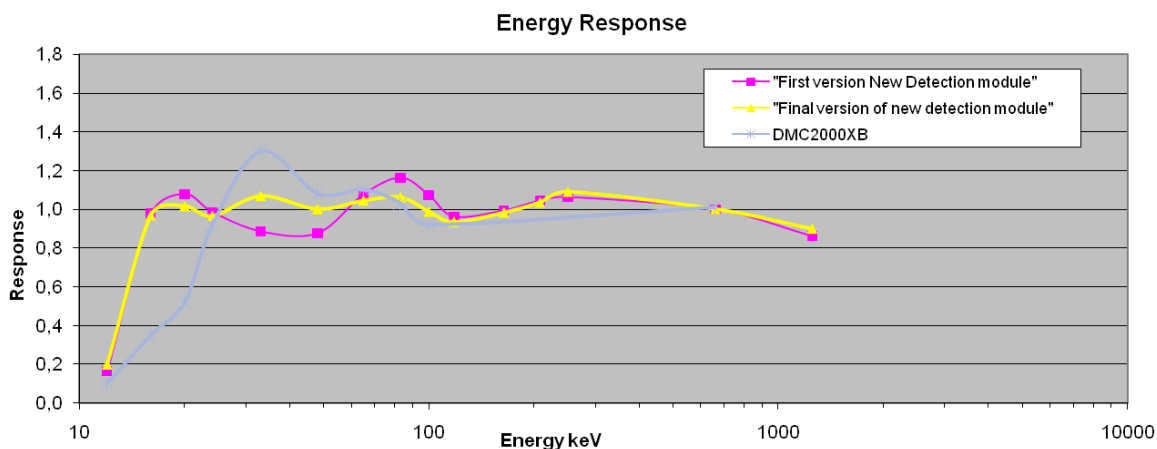


Figure 13: Energy response of DMC2000XB, first and final versions of the new detection module

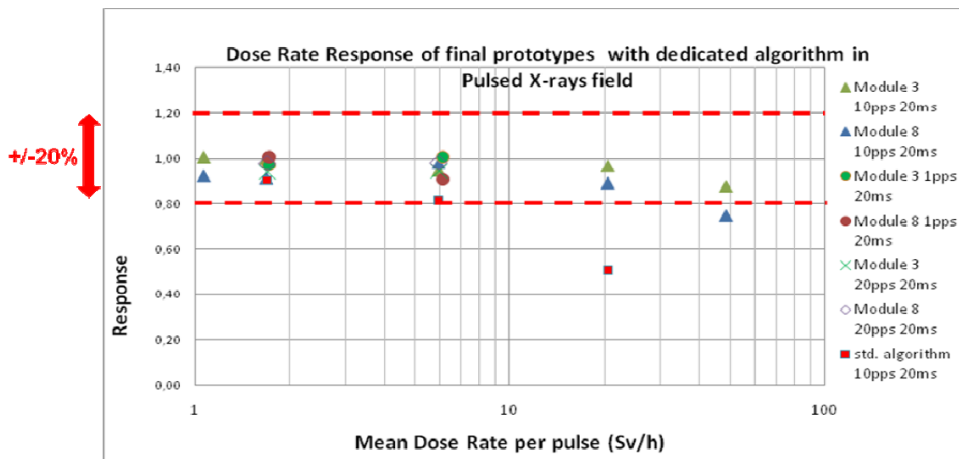


Figure 14: Dose rate response of the new detection module in pulsed field.

WP4: *Extremity dosimetry in nuclear medicine*

1. Measurement Campaign

a. Generalities

The objectives set out in WP4 were to evaluate extremity doses and dose distributions across the hands, to study the influence of protective devices and to propose “levels of indicative reference doses” for each standard nuclear medicine procedure, with the final goal of reducing, when possible, hand dose levels. One of the main tasks was to perform an extensive measurement campaign of hand doses in European hospitals using a unified measurement protocol.

b. Measurement protocol

The preparation and administration of both diagnostic and therapy procedures were studied. In diagnostics, radiopharmaceuticals labelled with ^{99m}Tc and ^{18}F were included in the investigations because of their wide use. For therapeutic procedures the studies were focused on ^{90}Y labelled radiopharmaceuticals such as Zevalin[®] and DOTATOC.

For each measurement, preparation and administration to the patient of the radiopharmaceutical, were separated. Eleven TLDs, calibrated to measure the personal dose equivalent $H_p(0.07)$, were taped on gloves at 11 positions of both left and right operator’s hands [wrist, of the thumb, first phalanx, (palmar side) and nail of index, middle and ring fingers]. For practical reasons in therapy a given pair of gloves was used for a single preparation (or administration). For diagnostics the gloves were used several times by the same operator in order to integrate significant doses in the TLDs. The identification of the hospital and operator were recorded, together with the manipulated activities, shield(s) used and any difficulty that could occur during the operations. For most of the operators the measurement was repeated 5 times. In diagnostics, those workers with less than 4 set of measurements were rejected

The TLDs used by the partners were of different types, either LiF:Mg,Ti or LiF:Mg,Cu,P with thickness ranging from 7 to 240 mg.cm⁻². An intercomparison exercise was done for reference x-, γ - and β -ray fields to ensure consistency of the results between different partners and to select specific techniques for specific applications, e.g. thin TLDs for ^{90}Y -based therapy.

The statistical analysis was performed with 641 measurements, collected in around 20 NM departments per procedure from 6 European countries (France, Spain, Belgium, Italy, Slovakia and Switzerland) (see Table 4). An overview of the measurements performed in NM therapy concerning ⁹⁰Y-labelled substances is summarised in Table 5.

Table 4. Number of NM departments, workers and measurements included in the statistical analysis.

| Procedure | Number of NM departments | Number of monitored workers | Number of measurements |
|----------------------------------|--------------------------|-----------------------------|------------------------|
| Preparation ^{99m} Tc | 21 | 36 | 178 |
| Administration ^{99m} Tc | 20 | 32 | 157 |
| Preparation ¹⁸ F | 17 | 30 | 160 |
| Administration ¹⁸ F | 17 | 30 | 146 |

Table 5: Overview of the measurements performed in the preparation (P) and administration (A) of ⁹⁰Y-labelled substances.

| Therapy | Procedure | Labs | Hospitals | Workers | Measurements |
|-----------------------------|-----------|------|-----------|---------|--------------|
| SIRS | P+A | 2 | 3 | 4 | 20 |
| PRRT | P | 3 | 3 | 5 | 16 |
| <i>DOTATOC</i> | A | 3 | 3 | 7 | 17 |
| RIT | P | 6 | 16 | 20 | 49 |
| <i>Zevalin</i> [®] | A | 6 | 15 | 22 | 45 |

For each radionuclide and procedure the analysis was performed independently. The normalized $H_p(0.07)$ ($\mu\text{Sv}/\text{GBq}$) measured at each of the 22 monitored positions were averaged over the series of measurements for each worker. These mean values were used for the analysis. The maximum normalized local skin dose was calculated as the highest of those 22 mean values.

The objectives of the statistical analysis were:

- To classify the workers according to their maximum normalized dose.
- To estimate the annual maximum local skin dose.
- To identify good and bad practices and relate them to working habits and parameters of influence.
- To analyze the dose distribution across the hands.
- To determine the frequency of the position where the maximum dose is received.
- To determine the best position for placing the extremity dosimeter and the possible underestimation at the available routine monitoring positions.

Many parameters and steps affect the local skin dose at hands, especially for preparation. In addition there was a lack of information on potential parameters of influence, such as the operation time. Furthermore, the tools to reduce finger doses (shields, forceps...) were sometimes used in some steps and not in others during a single measurement, or were either used differently from one measurement to another. The number of times that the activity was manipulated was not taken into account (e.g. number of tries to draw the radioactive liquid into a syringe to gain the right volume). In general, the fact that the measurements were not systematically watched or recorded on video could cause some important details to be missing. The problem is thus complex and therefore the analysis had to be kept simple. In spite of this, the study provides a good overview of the level of finger exposure from a wide range of working habits and working procedures.

c. Doses and dose distribution

Workers were classified according to their maximum dose, in increasing order. In Figures 15 and 16 the maximum dose of each worker is represented by a bar. The workers highlighted in Figure 16, were considered as outliers. Those workers have practices that significantly differed from those of the majority, leading to very high or very low exposures. It has been observed that most of the workers receiving very high doses did not use shielding for vials and/or syringes. On the other hand, those with very low exposures used semi-automatic equipment, which is not a common practice yet.

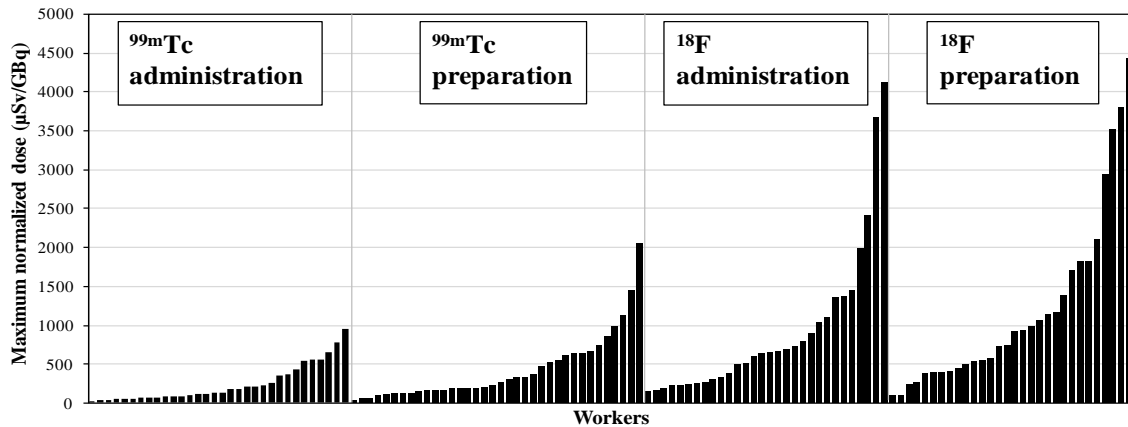


Figure 15. Maximum dose per worker classified for procedure and graded from the lowest to the highest dose (each bar corresponds to one worker).

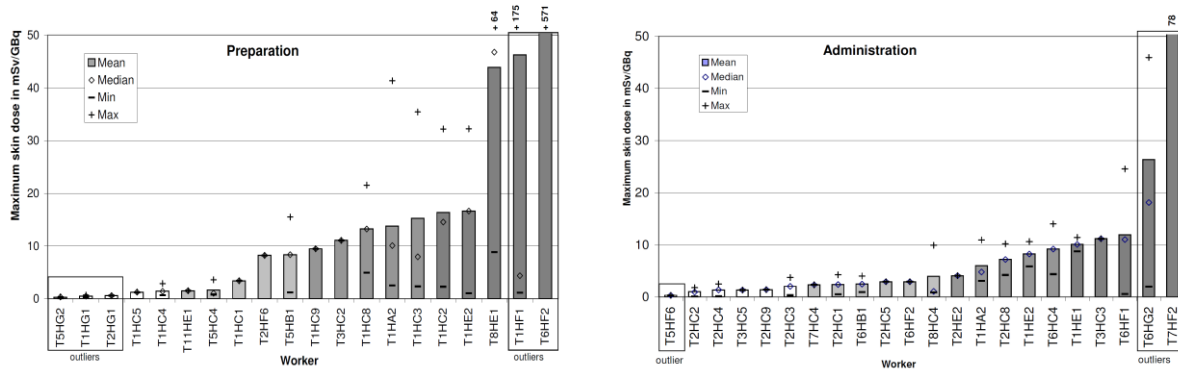


Figure 16. Classification of staff exposure in RIT with ⁹⁰Y/Zevalin® (each bar corresponds to one worker).

The range, mean and median values over the maximum doses were calculated for each procedure (Table 6 for diagnostics and Table 7 for therapy).

Table 6. Range, mean and median values of the maximum dose over all workers monitored per diagnostic procedure.

| Procedure | Maximum normalized dose (µSv/GBq) | | |
|----------------------------------|--------------------------------------|------|--------|
| | Range | Mean | Median |
| Administration ^{99m} Tc | 12 – 951 | 233 | 118 |
| Preparation ^{99m} Tc | 33 – 2062 | 432 | 249 |
| Administration ¹⁸ F | 139 – 4113 | 933 | 641 |
| Preparation ¹⁸ F | 97 - 4433 | 1205 | 828 |

Table 7. Maximum skin dose of staff in RIT with ⁹⁰Y/Zevalin®

| | Maximum dose in mSv/GBq | | | | | |
|------------------|-------------------------|--------|------------|----------------|--------|------------|
| | Preparation | | | Administration | | |
| | Mean | Median | Range | Mean | Median | Range |
| With outliers | 39.2 | 8.9 | 0.1 - 571 | 9.0 | 3.4 | 0.1 - 78.3 |
| Without outliers | 11.0 | 9.5 | 0.7 - 63.7 | 4.8 | 2.9 | 0.7 - 24.6 |

As shown in Tables 6 and 7, very large ranges of maximum doses were found for the same procedure. The preparation of radiopharmaceuticals involves higher finger doses per activity than for the administration, because the procedures are longer and there are more steps requiring manipulations of the vials/syringes with higher activities, some of them without shield.

The dose distribution across the hands was also studied. For all procedures it was observed that the non-dominant hand usually receives higher doses than the dominant hand. The frequency of the position where the maximum dose was received was also calculated for each procedure, considering the 22 positions of both hands. For all diagnostics and therapy procedures, the index tip of the non-dominant hand is the position where the maximum dose is most frequently received (from 22% to more than 60%), followed by the thumb of the same hand for almost all procedures (from 10% to 20%). Less frequently, the same positions of the dominant hand were also found to be common positions with maximum dose (up to 10%). In the majority of the therapy cases, as for diagnostics, the tip of the index finger or the thumb on the non-dominant hand was found to receive the maximum dose, especially in those cases where the exposure was high.

d. Parameters influencing the doses

In order to identify the parameters of influence on the skin dose, workers were classified into categories for those parameters for which information was available and whenever the amount of data in each category was large enough (representing at least the 10% of the total data). For all these cases the Mann Whitney-*U* test (SPSS v.17.0) was applied to analyze the differences between the skin doses received by workers within each of the categories. The results of the test did not show statistically significant differences between the doses received by experienced and beginner workers. On the other hand, the shield was found to be a very important parameter of influence both for the vial and for the syringe, causing the differences between the doses received when using shield and when not using it to be statistically significant. When feedback was given to workers after a measurement series, informing them of their exposures and with a discussion of bad practices in particular cases, a decreased dose was observed in the subsequent measurements. That is of particular importance for radiation protection optimization because it demonstrates that the correction of the bad habits, that usually requires a small effort, could imply a very large spare in extremity doses to the operator, e.g. by using shielding and tools to avoid any direct contact of the fingers with the source.

e. Routine monitoring

Wrist or ring dosimeters are typically used for routine monitoring. Although there is not a harmonized criterion for the position of the ring dosimeter, in practice it is usually placed at the base

of the index, middle or ring fingers of the dominant hand since these positions do not hamper work causing an underestimation of the maximum dose. The underestimation was assessed, in a first step, by calculating the correlations (linear correlation coefficients) between the dose at all measuring positions and the maximum dose. The skin dose was found to be well correlated to the maximum dose at all the positions for all diagnostics procedures (>0.6) and to most of the positions for therapy procedures. The tips of the fingers, especially those of the non-dominant hand, present the highest correlations, whereas the least correlated positions are the two wrists. Thus, although the routine monitoring positions do not correspond to the position of the maximum skin dose, they can be used to estimate this quantity.

In a second step the ratios between the maximum dose and the dose at relevant monitoring positions and at the index tip were calculated. The calculation was made for each single measurement and then averaged over the set of measurements of each worker. Some outliers (6% of the data) were excluded from the calculation, considering data causing the standard deviation of the mean to be higher than 20%. The calculation was made for all diagnostics procedures separately but the differences among procedures were not found to be relevant. Due to this reason and considering that NM workers are usually involved in more than one diagnostic procedure, the ratios were also calculated by including all data from all diagnostics procedures (Table 8). Tables 9 and 10 show the range, the median and the mean of the ratio between the maximum dose and the dose measured at relevant positions. It is obvious that the lowest ratio was found at the base of the index finger on the non-dominant hand.

Table 8. Range, median and mean values of the ratios between the maximum dose and the dose at the base of the index, base of the ring and tip of the index fingers.

| | Non-dominant hand | | | | Dominant hand | | | |
|--------|-------------------|----------------|---------------|---------------|---------------|----------------|---------------|---------------|
| | Max/wrist | Max/base index | Max/base ring | Max/index tip | Max/wrist | Max/base index | Max/base ring | Max/index tip |
| Range | 3 - 93 | 2 - 38 | 2 - 60 | 1 - 12 | 2 - 93 | 1 - 26 | 1 - 49 | 1 - 12 |
| Median | 16 | 4 | 7 | 2 | 14 | 5 | 8 | 2 |
| Mean | 20 | 6 | 10 | 2 | 18 | 6 | 10 | 3 |

Table 9. Range, median and mean values of the ratios between the maximum dose and the dose at the base of the index, base of the ring and wrist for staff during $^{90}\text{Y}/\text{Zevalin}^{\text{®}}$ preparation

| | Non-dominant hand | | | | Dominant hand | | | |
|--------|-------------------|----------------|---------------|---------------|---------------|----------------|---------------|---------------|
| | Max/wrist | Max/base index | Max/base ring | Max/index tip | Max/wrist | Max/base index | Max/base ring | Max/index tip |
| Range | 3 - 42 | 2 - 18 | 2 - 51 | 1 - 17 | 3 - 32 | 2 - 79 | 4 - 85 | 1 - 75 |
| Median | 12 | 6 | 11 | 2 | 15 | 15 | 22 | 5 |
| Mean | 15 | 6 | 12 | 3 | 15 | 24 | 34 | 19 |

Table 10. Range, median and mean values of the ratios between the maximum dose and the dose at the base of the index, base of the ring and wrist for staff during $^{90}\text{Y}/\text{Zevalin}^{\text{®}}$ administration

| | Non-dominant hand | | | | Dominant hand | | | |
|--------|-------------------|----------------|---------------|---------------|---------------|----------------|---------------|---------------|
| | Max/wrist | Max/base index | Max/base ring | Max/index tip | Max/wrist | Max/base index | Max/base ring | Max/index tip |
| Range | 5 - 102 | 3 - 18 | 1 - 89 | 1 - 7 | 2 - 46 | 3 - 60 | 2 - 90 | 1 - 29 |
| Median | 21 | 7 | 13 | 1 | 17 | 12 | 15 | 5 |
| Mean | 27 | 7 | 19 | 2 | 26 | 21 | 27 | 9 |

The mean ratios are significantly higher for the wrist positions. The lowest mean ratios were found for the index tip position. The ratios are also lower for the base of the index finger than for the base of the ring finger, and lower for the non-dominant hand than for the dominant one. Thus, according to these results, the use of wrist dosimeters should be avoided because of a very high underestimation and a lower correlation to the maximum dose. Ring dosimeters are recommended instead. If, for practical reasons the dosimeter cannot be placed at the finger tip, the most appropriate position is the base of the index finger of the non-dominant hand. In this position the mean underestimation would be around a factor of 6. The TLD must always be arranged on the palm side of the hand.

f. Extrapolation to annual doses

The annual dose of the monitored workers involved in diagnostic procedures for the ORAMED project has been estimated. For this estimation, only those procedures from which measured values, from the ORAMED measurement campaign, were available for a specific worker have been considered. Their workload and the activity manipulated per year for each radionuclide, was considered. As shown in Figure 17, the estimated annual dose is above 150 mSv, i.e. 3/10 of the annual limit, for 51% of the workers and for 20% of the workers the annual dose limit was exceeded.

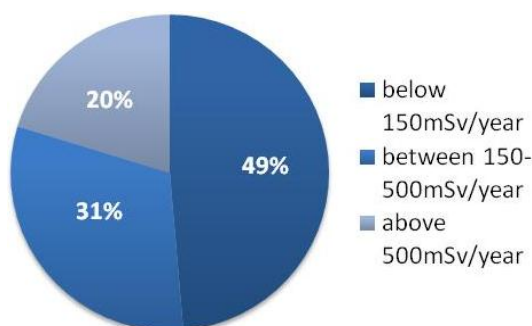


Figure 17. Percentage of workers with estimated annual local skin dose, below 150mSv, between 150 and 500mSv and above 500mSv.

It has to be noticed that the real situation is more complex since usually a given worker will not perform only one but several different procedures. Therefore, the annual maximum dose is likely to be an underestimation whenever the worker is actually involved in more procedures than those actually measured. The results of the estimation highlight the need to monitor the worker and to optimize the radiation protection standard in NM.

2. Simulation Campaign

Monte Carlo simulations were employed to determine at what extent the range of doses evaluated during measurements could be considered “intrinsically related” to those procedures and in which way it was possible to estimate the effectiveness of different adopted methodology and shielding, with such large variability of data. More than 200 simulations were performed. Voxel models representing the hands of the operator during some selected steps of administration and preparation procedures were obtained through the elaboration of CT scans of real phantoms.

The radioactive source was simulated as a cylinder of proper volume representing the manipulated syringe or the vials. A sensitivity analysis was performed changing the source describing properties as the volume, the distance from the hand, the thickness of the shielding for the same three radionuclides considered in the measurements.

Simulations show that depending on the radionuclides and on the voxel hand model, factors ranging from 0.5 to 3 can be reached only by considering small displacements (of the order of one or few centimetres) of the source with respect to the sensor positions. These fluctuations are of the order of those encountered in the analysis of the measurements results. This numerical quantification was important to support the robustness of the statistical analysis. Moreover, they showed the advantages concerning dose reduction of a correct use of the shielding during preparation of radiopharmaceuticals and of the convenience of employing forceps as an additional protective factor also in case of shielded sources.

Concerning the shielding, large reduction factors (2 to 3 orders of magnitude) can be obtained when using the appropriate shielding. The shielding material and thickness has to be adapted to the radionuclide manipulated.

With Monte Carlo simulations and dose mapping it was also possible to investigate at what extent the positions initially considered for the TLDs in the measurement program were suitable to estimate the maximum of the dose. As an example, in Figure 18 the dose mapping shows a maximum of 41 $\mu\text{Sv}/\text{GBq.s}$ located on the index and middle fingers inner surfaces. This value is underestimated by less than 20% by the nearest dosimeter located on the nail of the index. That allows us to say that for the majority of the cases, considering the intrinsic approximations of the models, we are not very far from the expected value and position of the “local dose maximum” on the hand.

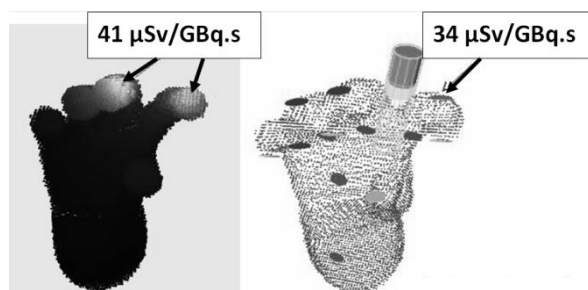


Figure 18. Dose mapping for the case of injection of ^{18}F : on the left the maximum obtained in the dose mapping for the unshielded syringe (the same level of grey corresponds to the same evaluated dose), on the right the doses calculated in the TLDs simulated position.

3. Recommendations

The following recommendations were derived from the observations and results of the WP4 of the ORAMED project:

- Extremity monitoring is a necessity in nuclear medicine, and a better control for the application of this legal requirement is needed.
- The base of the index finger of the non-dominant hand with the sensitive part of the dosimeter placed towards the inside of the hand is the recommended position for routine extremity monitoring in nuclear medicine.
- An estimate of the maximum dose to the hands can be obtained by multiplying the reading of the dosimeter worn at the base of the index finger of the non-dominant hand by a factor of 6.
- Shielding of vials and syringes is essential. This is a precondition but not a guarantee for low exposures. Any direct contact of the fingers to the needle - even though the syringe is shielded - must be avoided.
- The minimum acceptable thickness of shielding required for a syringe is 2 mm of tungsten for ^{99m}Tc and 5 mm of tungsten for ^{18}F . For ^{90}Y , 10 mm of PMMA completely shield beta radiation, but a shielding of 5 mm of tungsten provides a better protection, cutting down bremsstrahlung radiation too.
- The minimum acceptable shielding required for a vial is 3 mm and 3 cm of lead for ^{99m}Tc and ^{18}F , respectively. For ^{90}Y , an acceptable shielding is obtained with 10 mm of PMMA with an external layer of a few mm of lead.
- All tools increasing the distance (e.g. forceps, automatic injector) between the hands/fingers and the source are very effective for dose reduction.
- Training and education on good practices (e.g. procedure planning, repeating procedures using non radioactive sources, estimation of doses to be received) are more relevant parameters than worker's experience level itself.
- Working fast is not sufficient, the use of shields or increasing the distance are more effective than pushing on the working speed.

Concerning the estimation of exposures to be received, a dose estimation tool has been developed based on the ORAMED results and it is available via the ORAMED web site (<http://www.oramed-fp7.eu/>). This dose estimation tool provides values for the expected doses at 11 different points in each hand when preparing or injecting one the radionuclides studied within the ORAMED project (^{99m}Tc , ^{18}F or ^{90}Y Zevalin®), as shown in Figure 19.

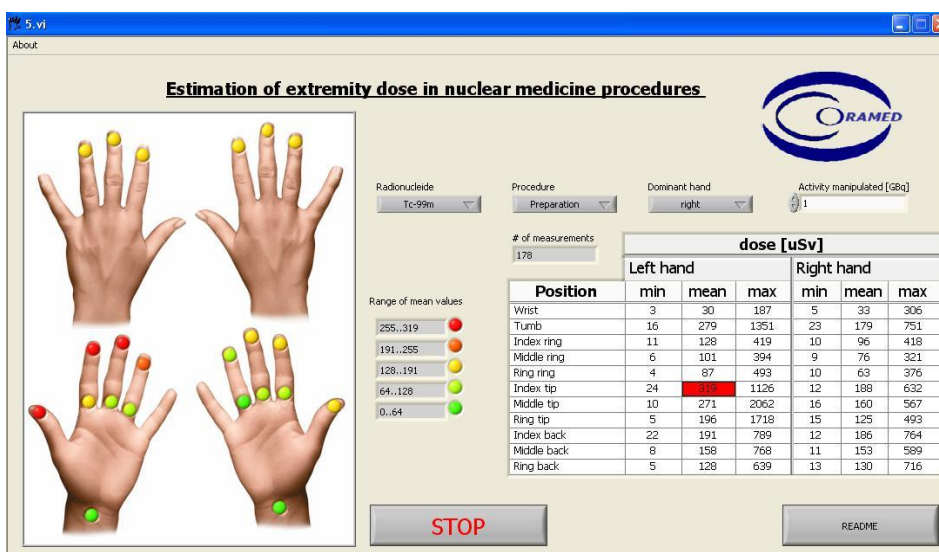


Figure 19. Dose estimation tool.

Potential impact and main dissemination activities and exploitation of results

The project was initially defined as an applied research project with technological development. Its development has fulfilled the foreseen objectives. The composition of the consortium with representatives from research institutes, universities, hospitals, government bodies and commercial companies, as well as the coupling of experimental dose measurements and high accuracy modelling capabilities, have been very useful to reach those objectives. The main achievements shall provide impact on the following fields and target groups:

1. Optimization of radiation protection of medical staff: recommendations to improve work practices in order to reduce the exposure to ionizing radiation. Target-group: Medical staff, Medical Physicists, Radiation Protection officers
2. Development of new products to better measure the ionizing radiation exposure of medical staff. Target-group: Dosemeter manufacturers, Medical Physicists, Radiation Protection officers
3. Development of new methodologies to measure eye-lens doses. Target-group: scientists in the field of metrology and dosimetry, dosimeter manufacturers.
4. Development of type-tests and calibration procedures for personal dosimeters to be used in interventional radiology and in extremity dosimetry in nuclear medicine. Target-group: scientists in the field of metrology and dosimetry, dosimeter manufacturers.
5. Potential impact on regulation in radiation protection and more specifically in individual monitoring. Target-group: policy maker, regulators, radiation protection officers.
6. Improvements in training on radiation protection for medical staff. Target-group: Medical Physicists, Radiation Protection officers, University Lecturers, Teachers of technician schools.

1. Optimization of radiation protection of medical staff: recommendations to improve work practices in order to reduce the exposure to ionizing radiation.

1.1 Interventional radiology and interventional cardiology

The measurement and simulation campaign performed in the field of interventional radiology and interventional cardiology within the ORAMED project revealed a large variability of practices followed in different hospitals. It is demonstrated that, in general there are a large number of parameters that affect the extremity and eye lens doses.

Medical staff in interventional radiology should follow the following recommendations to reduce their level of exposure to radiation.

- Only dedicated interventional equipment and rooms (properly shielded) should be used.
- Personal protective equipment should be used (at least collar and lead aprons). Lead glasses with side shield should be preferred.
- The room protective equipment should be used and positioned properly.
- The ceiling suspended shield should be placed as close to the patient as possible. The combination of transparent ceiling shield and lead drapes that touch the patient is very efficient for the protection of the eyes and hands.
- If biplane systems are used an extra ceiling shield to reduce the scattered radiation from the lateral tube is very important for the protection of the eyes. It is more effective if it is positioned at the side of the operator (or next to the operator).

- The tube should be placed below the operating table. The higher doses at the legs in this setup can be reduced by a properly positioned table shield.
- Care should be taken for the table shield when the operators need to move around the table for medical reasons.
- Mobile floor shield should be used for the assisting personnel that need to be in the irradiation room.
- The femoral access should be preferred whenever it is possible from the medical point of view.
- Going outside the operating room during the image acquisition is a practice which can reduce the doses significantly.
- Avoid direct exposure of hands to primary radiation.

The effectiveness of the proposed recommendations can be checked by using the appropriate dosimetric systems.

- Monitoring of the eyes and fingers (or wrists) should be performed on routine basis. The dosimeters should be worn on the side of the operator which is closest to the X ray tube. The dosimeter should be placed on the dorsal or palmar side of the hand when the X ray tube is placed above or below the operating table, respectively.
- Active personal dosimeters (APD) worn above the lead apron are recommended as operational personal dosimeter, especially for radiologists and cardiologists. Their use will increase the awareness of the personnel while they are in the operating room. Prior the selection of an active personal dosimeter, one should make sure that the device is appropriate to measure low-energy photons and pulsed radiation fields (see paragraph 4.2 for APD technical requirements).

1.2 Nuclear medicine

In nuclear medicine, the ORAMED project demonstrated a large variability of measured doses in the different hospitals depending on the radiation protection means and the operator's habits. The *sensitivity analysis* carried out through Monte Carlo simulations employing *voxel* models, representing operator's hand during the considered practices was found to be very useful in order to better understand the influences of the parameters of interest to reduce the dose of the personnel.

Nuclear medicine staff should follow the following recommendations to reduce their skin dose during the preparation (labelling) and injection of radiopharmaceuticals.

- Shielding of vials and syringes should be used when handling radiopharmaceuticals.
- Recommended shielding:
 - The minimum acceptable thickness of shielding required for a syringe is 2 mm of tungsten for ^{99m}Tc and 5 mm of tungsten for ^{18}F . For ^{90}Y , 10 mm of PMMA completely shield beta radiation, but a shielding of 5 mm of tungsten provides a better protection cutting down Bremsstrahlung radiation, too.
 - The minimum acceptable shielding required for a vial is 3 mm and 3 cm of lead for ^{99m}Tc and ^{18}F , respectively. For ^{90}Y , an acceptable shielding is obtained with 10 mm of PMMA with an external layer of a few mm of lead.
- Any tool increasing the distance (e.g. forceps, automatic injector) between the hands/fingers and the source is effective for dose reduction.
- The use of shielding and tools to increase distance between the hands and the source are a precondition but not a guarantee for low exposures. Training and education on good practices were found to be essential. (e.g. procedure planning, repeating procedures using non radioactive sources, estimation of doses to be received).

- Working fast is not always sufficient. The use of shields, together with the help of tools to increase the distance to the source are, in general, more effective.

ORAMED project showed that the skin effective dose limit could be exceeded while handling radiopharmaceuticals. Since the dose limit for the skin (500 mSv/year) must be applied to 'the dose averaged over any area of 1 cm² regardless of the area exposed', some recommendations on extremity monitoring in nuclear medicine are given to have a good estimate of the maximum skin doses.

- When measuring extremity doses in nuclear medicine practices, the effective thickness of the dosimeter and the position to wear it are important matters of concern. Thin detectors should be used when handling positron or beta emitters.
- The base of the index finger of the non-dominant hand with the sensitive part of the dosimeter placed towards the inside of the hand is the recommended position for routine extremity monitoring in nuclear medicine.
- A rough estimate of the maximum dose to the hand can be obtained by multiplying the reading of the dosimeter worn at the base of the index finger of the non-dominant hand by a factor of 6.

1.3 Summary

The recommendations given in paragraphs 1.1 and 1.2 provide guidelines to medical staff to adjust their way of working in order to reduce their exposure to radiation. They are also of interest to medical physicists and radiation protection officers in order to select the best radiation protection means and to improve the personal dosimetry systematic. These recommendations were first presented in the ORAMED workshop in Barcelona in January 2011, and are now available at the project website as leaflets that can be distributed to target groups (www.oramed-fp7.eu). They should lead to a decrease of the occupational doses of medical staff.

2. Development of new products to better measure the ionizing radiation exposure of medical staff

The collaboration between two commercial companies and research institutes, in particular national calibration laboratories, has allowed the development of two innovative prototypes to improve personal dose monitoring in interventional radiology.

2.1 Development of a practical eye lens dosimeter

In recent years an increased occurrence of radiation related lens opacities and cataracts for interventional radiologists have been reported. However, the eye lens doses are hardly ever measured in practice. In the framework of ORAMED, an eye lens TL dosimeter has been developed, optimised and tested. The dosimeter is now under the process of being patented by Radcard s.c. under the commercial name EYE-D. A sample of an EYE-D and a commercial leaflet were distributed to ORAMED 2011 workshop participants.

This is the first dosimeter available commercially specially designed to provide precise measurements of radiation dose to eye lens. It can be worn close to the eye and presents a good angular and energy response in terms of $H_p(3)$.

2.2 Development of an improved APD for interventional radiology

Up to now, APDs were not specifically designed to be used in interventional radiology typical radiation fields. The main limitations were due to the need to respond at high dose rates during short time intervals. A prototype called was developed by MIRION Technologies. Performance of the prototype is promising and it is foreseen that shortly a new product will be available.

The first improvement on the prototype consisted in having a response that did not depend more than +/- 10% all over the energy range of interest used in IR/IC procedures. In addition the detection module was re-designed so that the dosimeter angular response was improved to a maximum deviation of +/-30% for angles up to +/-65°. Finally, the dead-time compensation correction was adjusted to present a satisfactory response up to dose rates of 10 Sv.h⁻¹ in continuous fields and up to 20 Sv.h⁻¹ in pulsed fields.

2.3 Summary

The new products developed in the framework of ORAMED cover two important lacks identified in the field of individual monitoring in interventional radiology and interventional cardiology. The continuous feedback between manufacturers and scientists has been essential for the developments. Thus, the study has already had a first positive impact for the companies in charge of the development, and can be of interest to other dosimeter manufacturers.

In addition, the new devices will be useful tools for increasing awareness of medical staff on radiation exposure and for having a better assessment of personal doses in interventional radiology, in particular for the measurement of the eye lens dose. High impact in radiation protection methods is foreseen both in Europe and worldwide.

3. Development of new methodologies to measure eye-lens doses.

$H_p(3)$ is defined as the operational quantity to control the eye lens legal dose limits. However, in 2008, at the beginning of the project, there was no international agreement on how to reproduce this quantity in laboratory and how it could be related to basic dosimetry quantities. The theoretical investigation on the operational quantity $H_p(3)$ undertaken in the project has provided a set of new conversion coefficients from K_a to $H_p(3)$, defined on a new model of phantom (a cylinder of 20 cm diameter and 20 cm height). The proposed formalism has been essential for the development of the eye lens dosimeter (paragraph 2.1) and for the definition of calibration methods in this field (paragraph 4.1).

The conversion coefficients from air kerma to personal dose equivalent $H_p(3)$ for eye-lens dosimetry are tabulated in ENEA report (F. Mariotti, G. Gualdrini, RT/2900/1/Bas, Bologna, 2009) and in CEA Rapport (J. Daures, J. Gouriou, J.M. Bordy, CEA-R-6235, Paris, 2009) (ISSN 0429-3460).

International organisations, such as the International Commission on Radiation Units and Measurements (ICRU) and the International Commission on Radiation Protection (ICRP) have been contacted to inform them on the results in the study so that it can be considered in the development of new standards and international recommendations.

3.3 Summary

A framework for the measurement and calibration of the operational quantity for eye lens dosimetry has been developed, and this will improve the measurement and standardization of the eye lens dose measurements for many years to come.

4. Development of type-tests and calibration procedures for personal dosimeters to be used in interventional radiology

A large number of international type-test and calibration standards are available for individual monitoring purposes. However, in the field of medical applications, there are several limitations that can be overcome by following some of the recommendations proposed in the framework of ORAMED.

4.1 Type-test and calibration of eye-lens dosimeters

A proposal for the type test and calibration of eye lens passive dosimeters especially used in interventional radiology and interventional cardiology (IR/IC) has been prepared. The proposal starts from the only one existing standard dealing with eye lens dosimetry using TLDs (ISO 12794), and proposes technical requirements for parameters such as, detection threshold, energy and angle responses. The recommended requirements are based on ISO 12794 and IEC 62387 and take into account the particular use of those dosimeters at IR/IC workplaces.

The proposal adopts the methodology developed in ORAMED project to reproduce and calculate in laboratory the operational quantity $H_p(3)$ (paragraph 3). Conversion coefficients from air kerma to dose equivalent at 3 mm depth for RQR and ISO radiation qualities are presented in the proposal and the new water cylindrical phantom introduced by ORAMED is recommended for type-test and calibration. These proposals and coefficients should be taken into account by the international standard organisations when revising the relevant standards to allow a better estimate of H_{lens} .

4.2 Type-test and calibration of APDs to be used in interventional radiology

The IEC 61526 standard is the international standard to be applied for type-testing of APDs. However, as pulsed radiation fields are not taken into account in existing standards, some information on the APD characteristics in pulsed field similar to those met at workplace are needed (i.e. effect of pulse frequency and width on the dose equivalent response) prior to using them in these fields.

The ORAMED project provides several guidelines to help the end-user in the selection and verification of the APD. Different sources of information are recommended: the results of the tests performed within the ORAMED project, specific ad-hoc tests performed by the manufacturers or some own tests performed in situ by the user.

4.3 Summary

The proposal summarized in paragraph 4.1 provides guidelines to calibration labs to perform calibration of eye-lens dosimeters and to derive the operational quantity from the reference air kerma value.

Recommendations described in paragraph 4.2 should be used by medical physicists and radiation protection officers in order to select the best active personal dosimeter for their service and to make sure that their device will be appropriate for their use. The recommendations were first presented in the ORAMED workshop in Barcelona in January 2011, and are now available at the project website, as leaflets that can be distributed to target groups (www.oramed-fp7.eu). Several manufacturers, present at ORAMED 2011, showed high interest on the results on APDs, both in laboratories and hospitals, and encouraged the idea about having regular independent tests, as the ones performed in ORAMED.

5. Potential impact on regulation in radiation protection and more specifically in individual monitoring. Target-group: policy maker, regulators, radiation protection officers.

The radiation protection recommendations and calibration guidelines are of interest to regulators and policy makers, on the one hand to disseminate good practices, and on the other to up-date knowledge in radiation protection of medical staff and thus define reference levels and regulations for extremity dosimetry. Extremity dosimetry is far less developed in Europe than whole body dosimetry and there is a lack of systematic data. The situation is even worst in the case of eye-lens doses which are hardly ever measured or estimated. The results of the study highlight the importance of monitoring the wrists or fingers and eye lens.

In recent years there is growing epidemiological evidence of excess risk at the radiation doses measured within ORAMED, however, very often, dose assessment is not comprehensive in those studies. Moreover, the system of radiological protection is mainly based on excess risk of cancer induced by ionizing radiation and only little information is available on non-cancer effects, such as cardio-vascular disease and lens opacities. The dose data base obtained in the ORAMED project will be of great use to contribute to new research on risks related to occupational doses.

Representatives of most European Radiation Protection Regulator Bodies were present at ORAMED 2011.

6. Improvements in training on radiation protection for medical staff. Target-group: Medical Physicists, Radiation Protection officers, University Lecturers, Teachers of technician schools.

Training material within the topics of the project has been prepared. Several proposals are available, specifically designed for different target-groups.

Material for medical staff. It consists of two 2 h-modules based on the experience of the project and taking advantage of images of practical situations as well as adapted to be used with interactive systems.

Module 1: Interventional radiology

Module 2: Nuclear medicine

Material for trainers. Since there is already general training material available, we have prepared some recommendations on what training material could be used in each field and how this general information can be completed with the specific modules developed within ORAMED. IRSN has prepared some guidelines mainly based on IAEA modules available from the web site: http://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Training/1_TrainingMaterial/index.htm

Material for dosimetry services and metrology labs. 1 hour module specifically prepared for dosimetry services and metrology labs, focused on recommendations for the calibration of dosimeters to be used in interventional radiology. It has been prepared by CEA.

Videos: SMU prepared a video for interventional radiology, showing how ORAMED measurements were performed (English version available). BfS prepared a video on Y-90 DOTA therapy. It includes good recommendations on radiation protection measures (English and German versions available).

Training material and videos are available at the ORAMED website and were presented during the ORAMED 2011 workshop.

Dissemination activities

- ORAMED 2011 workshop

The International Workshop on Optimization of Radiation Protection of Medical Staff, ORAMED 2011 was organized from the 20 to 22 January 2011, in the School of Industrial Engineering of Barcelona at UPC (Spain).

The workshop, chaired by Mercè Ginjaume, was organized by the UPC with the collaboration of the ten other ORAMED partners. Together with the ORAMED consortium partners, the programme Committee, chaired by the ORAMED coordinator, Filip Vanhavere from SCK-CEN, counted on the collaboration of the Directorate General of R & D of the European Commission, the International Atomic Energy Agency (IAEA), the European Radiation Dosimetry Laboratory Consortium (EURADOS), the Spanish Nuclear Safety Council (CSN), the Spanish Radiation Protection Society (SEPR) and the School of Industrial Engineering of Barcelona (ETSEIB).

The proposed topics attracted considerable interest internationally. There were 155 participants from 31 countries: 16 EC and 10 non EC European countries, the United States, Canada, Japan, Costa Rica and Sudan. 70 papers were submitted of which 20 in the form of posters and 25 as invited papers. Oral presentation slides are available at the workshop website. <http://www.upc.edu/inte/oramed>. Oral presentation papers will be published, after a review process, in a special issue of Radiation Measurement journals.

- Participation in scientific international conferences:

The main events where ORAMED was present were:

- *WC2009, World Congress 2009, Medical Physics and Biomedical Engineering. September 2009, Munich. 1 invited, 1 oral presentation and 1 poster. Abstracts published in special issue.*
- *ETRAP 2009, 4th International Conference on Education and Training in Radiological Protection, November 2009, Lisbon: 1 oral presentation.*
- *EANM'09- Annual Congress of the European Association of Nuclear Medicine. October 2009, Barcelona. Abstract in special issue European Journal of Nuclear Medicine and Molecular imaging: 1 oral presentation.*
- *IM 2010, European Conference on Individual Monitoring of Ionizing Radiation, Athens, March 2010: 1 invited talk, 3 oral presentations and 2 posters. 5 papers, published in a special issue of Radiation Protection Dosimetry.*
- *ENC2010, European Nuclear Conference, Barcelona, June 2010: 1 oral presentation.*
- *IRPA 2010, Third European IRPA Congress, Helsinki, June 2010: 2 oral presentations.*
- *SSD16, 16th Solid State Dosimetry Conference, Sidney, September 2010: 1 poster, the paper is under revision for publication in Radiation Measurements.*
- *Int. Symposium on Standards, Applications and Quality assurance in Medical Radiation Dosimetry (IAEA). (Vienna, November 2010) 1 oral presentation, 1 poster*
- *Int. Conference on Radiation Protection in Medicine (Varna, September 2010) 1 oral presentation and 1 poster.*
- *ORAMED 2011, Int. Workshop on Radiation Protection of Medical staff, Barcelona, January 2011: 2 invited talks, 20 oral presentations, 2 training sessions, 2 posters.*

In addition, presentations have been given to most national conferences in the topics studied in ORAMED and the final results will continue to be presented during 2011 and beginning of 2012 in international conferences such as ALARA 2011, ESR 2011, EANM'11, IRPA2012 .

- *Training exchange programme for young researchers.*

Seven stages have been organized between the different groups, to let the young researchers learn from the experience of other partners and to harmonize work. One of the stages at IRSN has been performed in the framework of the “European” PhD recognition for the thesis of A. Carnicer from UPC.

- *Participation of ORAMED members to training activities organised by international institutions and professional societies:*

- FP7 project MADEIRA training course (S. Krim), Malmo November 2009
- IAEA, Workshop on Occupational Radiation Protection in Medicine (M. Ginjaume) San José, Costa Rica, May 2010
- EANM’10 (M. Sans-Mercè) Vienna, October 2010
- ORAMED 2011, (M. Sans-Merce, M. Ginjaume, E. Carinou, F. Vanhavere, L. Struelens) Barcelona, January 2011
- Winter school of EURADOS (F. Vanhavere, E. Carinou, I. Clairand, G. Gualdrini, M. Sans) Prague, February 2011

- *ORAMED website* (www.oramed-FP7.eu)

The ORAMED website is hosted by the SCK-CEN information on the scope, objectives and main achievements is available. The website will be maintained up to 5 years after completion of the project. Training material, guidelines and list of publications are available. A new format will soon be introduced to increase the ease of maintenance.

- The address of the project public website:

ORAMED website: www.oramed-fp7.eu

ORAMED logo:



List of ORAMED beneficiaries and main contact persons:

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|---|---------|----|-------------------|--------------------------|
| Laboratoire National Henri Becquerel (LNE-LNHB) at the Commissariat à l'Energie atomique (CEA/LIST) | CEA | FR | Jean-Marc Bordy | Jean-Marc.BORDY@cea.fr |
| Slovak Medical University | SMU | SK | Denisa Nikodemova | denisa.nikodemova@szu.sk |
| Nofer Institute of Occupational Medicine | NIOM | PL | Joanna Domienik | jdom@imp.lodz.pl |
| Federal Office for Radiation Protection | BfS | DE | Arndt Rimpler | arimpler@bfs.de |
| RADCARD | RADCARD | PL | Pawel Bilski | pawel.bilski@radcard.pl |
| MGP Instruments | MGPI | FR | Pascal Martin | PMARTIN@mirion.com |

4.2 Use and dissemination of foreground

A plan for use and dissemination of foreground (including socio-economic impact and target groups for the results of the research) shall be established at the end of the project. It should, where appropriate, be an update of the initial plan in Annex I for use and dissemination of foreground and be consistent with the report on societal implications on the use and dissemination of foreground (section 4.3 – H).

The plan should consist of:

- Section A

This section should describe the dissemination measures, including any scientific publications relating to foreground. **Its content will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

- Section B

This section should specify the exploitable foreground and provide the plans for exploitation. All these data can be public or confidential; the report must clearly mark non-publishable (confidential) parts that will be treated as such by the Commission. Information under Section B that is not marked as confidential **will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

Section A (public)

This section includes two templates

- Template A1: List of all scientific (peer reviewed) publications relating to the foreground of the project.
- Template A2: List of all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

These tables are cumulative, which means that they should always show all publications and activities from the beginning until after the end of the project. Updates are possible at any time.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

| NO. | Title | Main author | Title of the periodical or the series | Number, date or frequency | Publisher | Place of publication | Year of publication | Relevant pages | Permanent identifiers (if available) | Is/Will open access provided to this publication? |
|-----|---|---------------|---------------------------------------|---------------------------|-----------|----------------------|---------------------|----------------|--------------------------------------|---|
| 1 | International activities related to medical staff dosimetry | D. Nikodemova | Conference proceedings | SBN 978-80-89384-01-3 | | Slovakia | 2008 | pp 252-255 | | |
| 2 | Staff extremity exposure in interventional cardiology: Results of the ORAMED workshop | L. Donadille | Radiation Measurements | Submitted | Elsevier | | 2012 | | | |
| 3 | Study of the parameters affecting operator doses in interventional radiology using Monte Carlo simulations | C. Koukorava | Radiation Measurements | Submitted | Elsevier | | 2012 | | | |
| 4 | Extremity doses of medical staff involved in interventional radiology and cardiology: Correlations and annual doses | S. Krim | Radiation Measurements | Submitted | Elsevier | | 2012 | | | |

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|----|--|-------------------------|---------------------------------------|--------------------------------|---|--|-------------|------------------|--|
| | <i>(hands and legs)</i> | | | | | | | | |
| 5 | <i>Optimization of staff extremity doses in interventional radiology. Results of the ORAMED measurement campaign</i> | <i>D. Nikodemova</i> | <i>Radiation Measurements</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | |
| 6 | <i>Measurements of eye lens doses in interventional radiology and cardiology: Final results of the ORAMED project</i> | <i>F. Vanhavere</i> | <i>Radiation Measurements</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | |
| 7 | <i>Recommendations to reduce extremity and eye lens doses in interventional radiology and cardiology</i> | <i>E. Carinou</i> | <i>Radiation Measurements</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | |
| 8 | <i>Occupational radiation doses to the extremities and the eyes in interventional radiology and cardiology procedures</i> | <i>E Efstathopoulos</i> | <i>British Journal of Radiology</i> | <i>84(997)</i> | <i>The British Institute of Radiology</i> | | <i>2011</i> | <i>Pp 70 -77</i> | |
| 9 | <i>Monte Carlo calculations on extremity and eye lens dosimetry for medical staff at interventional radiology procedures</i> | <i>E. Carinou</i> | <i>Radiation Protection Dosimetry</i> | <i>Doi 10.1093/rpd/ncq573</i> | <i>Oxford Universtity Press</i> | | <i>2010</i> | | |
| 10 | <i>Extremity and eye lens doses in interventional radiology and cardiology procedures: first results of the ORAMED project</i> | <i>J. Domienik</i> | <i>Radiation Protection Dosimetry</i> | <i>Doi: 10.1093/rpd/ncq508</i> | <i>Oxford Universtity Press</i> | | <i>2010</i> | | |
| 11 | <i>Doses to operators during interventional radiology procedures: focus on eye lens and extremity dosimetry</i> | <i>C. Koukorava</i> | <i>Radiation Protection Dosimetry</i> | <i>Doi 10.1093/rpd/ncq328</i> | <i>Oxford Universtity Press</i> | | <i>2010</i> | | |
| 12 | <i>Active personal dosimeters in interventional radiology: tests in laboratory conditions and in hospitals</i> | <i>I. Clairand</i> | <i>Radiation Protection Dosimetry</i> | <i>Doi 10.1093/rpd/ncq556</i> | <i>Oxford Universtity Press</i> | | <i>2010</i> | | |
| 13 | <i>Use of Active personal dosimeters in interventional radiology/cardiology: tests in hospitals.</i> | <i>L. Struelens</i> | <i>Radiation Measurement</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | |
| 14 | <i>Use of active personal dosimeters in interventional</i> | <i>I. Clairand</i> | <i>Radiation Measurement</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | |

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|----|---|----------------------|---------------------------------------|-------------------------------|---------------------------------|--|-------------|-------------------|--|
| | <i>radiology/cardiology: tests with continuous and pulsed fields in laboratory conditions – ORAMED project</i> | | | | | | | | |
| 15 | <i>Extremity dosimeter based on LiF(Mg,Cu,P) to measure Hp(3,α)</i> | <i>F. Mariotti</i> | <i>Radiation Protection Dosimetry</i> | <i>Doi 10.1093/rpd/ncq548</i> | <i>Oxford Universtity Press</i> | | <i>2011</i> | | |
| 16 | <i>Eye lens dosimetry: task 2 within the ORAMED project</i> | <i>G. Gualdrini</i> | <i>Radiation Protection Dosimtry</i> | <i>Doi 10.193/rpd/ncr011</i> | <i>Oxford Universtity Press</i> | | <i>2011</i> | <i>Pp 473-477</i> | |
| 17 | <i>Monte Carlo determination of the conversion coefficient Hp(3)/Kair in thea right cylinder phantom with "PENELOPE" code. Comparison with "MCNP" simulations</i> | <i>J. Daures</i> | <i>Radiation Protection Dosimtry</i> | <i>Doi 10.193/rpd/ncq359</i> | <i>Oxford Universtity Press</i> | | <i>2011</i> | <i>Pp 37-42</i> | |
| 18 | <i>Principle for the design of radiation protection dosimeters for operational and protection quantities</i> | <i>J.M. Bordy</i> | <i>Radiation Protection Dosimetry</i> | <i>Doi 10.193/rpd/ncr010</i> | <i>Oxford Universtity Press</i> | | <i>2011</i> | <i>Pp 257-261</i> | |
| 19 | <i>Eye-Lens Dosimetry – outcomes of the ORAMED Project</i> | <i>G. Gualdrini</i> | <i>Radiation Measurement</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | |
| 20 | <i>Proposal for Eye-Lens Dosimeter Calibration and Type Testing</i> | <i>J.M. Bordy</i> | <i>Radiation Measurement</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | |
| 21 | <i>A New Dosimeter for Measurements of Hp(3) for medical staff</i> | <i>P. Bilski</i> | <i>Radiation Measurement</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | |
| 22 | <i>Extremity exposure in nuclear medicine : preliminary results of a european study</i> | <i>M. Sans Merce</i> | <i>Radiation Protection Dosimetry</i> | <i>doi:10.1093/rpd/ncq574</i> | <i>Oxford Universtity Press</i> | | <i>2011</i> | <i>Pp 515-520</i> | |
| 23 | <i>The use of different types of thermoluminescent dosimeters to measure extremity doses in nuclear medicine</i> | <i>A. Carnicer</i> | <i>Radiation Measurement</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | |

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| 24 | <i>Extremity Exposure in Nuclear Medicine Therapy with 90Y labelled substances- Results of the ORAMED project.</i> | <i>A. Rimpler</i> | <i>Radiation Measurement</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | | |
| 25 | <i>Extremity exposure in diagnostic nuclear medicine with 18F and 99mTc labelled radiopharmaceuticals - Results of the ORAMED project</i> | <i>A. Carnicer</i> | <i>Radiation Measurement</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | | |
| 26 | <i>Recommendations to reduce hand exposure for standard nuclear medicine</i> | <i>M. Sans Merce</i> | <i>Radiation Measurement</i> | <i>Submitted</i> | <i>Elsevier</i> | | <i>2012</i> | | | |
| 27 | <i>Eye lens and extremity doses for staff working in interventional radiology and cardiology departments -first results of Oramed project</i> | <i>J. Domienik</i> | <i>Conference proceedings</i> | <i>ISBN 978-83-61856-01-6</i> | | <i>Poland</i> | <i>2010</i> | <i>pp 47-51</i> | | |

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

| NO. | Type of activities | Main leader | Title | Date | Place | Type of audience | Size of audience | Countries addressed |
|-----|--------------------------|----------------|--|---------------------------|--------------------------|---|------------------|---|
| 1 | <i>Workshop</i> | <i>UPC</i> | <i>Workshop on Optimization of Radiation Protection of Medical Staff</i> | <i>20-22 January 2011</i> | <i>Barcelona</i> | <i>Scientific Community, Policy makers, Medical staff</i> | <i>155</i> | <i>31 countries: 16 EC and 10 non EC European countries</i> |
| 2 | <i>Website</i> | <i>SCK•CEN</i> | <i>ORAMED: Optimization of Radiation Protection of Medical Staff</i> | | <i>www.oramed-fp7.eu</i> | <i>Scientific Community, Policy makers, Medical staff</i> | | |
| 3 | <i>Video</i> | <i>SMU</i> | <i>Interventional radiology: measurements</i> | | | <i>Scientific Community, Medical staff</i> | | |
| 4 | <i>Video</i> | <i>BfS</i> | <i>Y-90: DOTA therapy</i> | | | <i>Scientific Community, Policy makers, Medical staff</i> | | |
| 5 | <i>Training material</i> | <i>GAEC</i> | <i>Interventional Radiology training module</i> | | | <i>Scientific Community, Policy makers, Medical staff</i> | | |
| 6 | <i>Training material</i> | <i>CHUV</i> | <i>Nuclear medicine: training material</i> | | | <i>Scientific Community, Policy makers,</i> | | |

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|----|--------------|---------------|---|--------------------|---------------------------|--|-----|--|
| | | | | | | Medical staff | | |
| 7 | Presentation | M. Brodecki | Staff extremity exposure in interventional cardiology: Results of the ORAMED workshop | 20-22 January 2011 | ORAMED workshop Barcelona | Scientific Community, Policy makers, Medical staff | 155 | 31 countries: 16 EC and 10 non EC European countries |
| 8 | Presentation | C. Koukorava | Study of the parameters affecting operator doses in interventional radiology using Monte Carlo simulations | 20-22 January 2011 | ORAMED workshop Barcelona | Scientific Community, Policy makers, Medical staff | 155 | 31 countries: 16 EC and 10 non EC European countries |
| 9 | Presentation | S. Krim | Extremity dosimetry in interventional radiology and cardiology: Correlations and extrapolations to annual doses | 20-22 January 2011 | ORAMED workshop Barcelona | Scientific Community, Policy makers, Medical staff | 155 | 31 countries: 16 EC and 10 non EC European countries |
| 10 | Presentation | D. Nikodemova | Optimization of staff extremity doses in interventional radiology. Results of the ORAMED measurement campaign | 20-22 January 2011 | ORAMED workshop Barcelona | Scientific Community, Policy makers, Medical staff | 155 | 31 countries: 16 EC and 10 non EC European countries |
| 11 | Presentation | F. Vanhavere | Measurements of eye lens doses in interventional radiology and cardiology: Final results of the ORAMED project | 20-22 January 2011 | ORAMED workshop Barcelona | Scientific Community, Policy makers, Medical staff | 155 | 31 countries: 16 EC and 10 non EC European countries |
| 12 | Presentation | J. Domienik | Recommendations to reduce extremity and eye lens doses in interventional radiology and cardiology | 20-22 January 2011 | ORAMED workshop Barcelona | Scientific Community, Policy makers, Medical staff | 155 | 31 countries: 16 EC and 10 non EC European countries |
| 13 | Presentation | J. Domienik | Extremity and eye lens doses in interventional radiology and cardiology procedures: first results of | March 2010 | IM2010, Athens | Scientific Community, Policy makers, | 400 | |

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|----|---------------------|---------------------|---|---------------------------|----------------------------------|---|------------|---|
| | | | <i>the ORAMED project</i> | | | <i>Dosimetry community</i> | | |
| 14 | <i>Presentation</i> | <i>I. Clairand</i> | <i>Active personal dosemeters in interventional radiology: tests in laboratory conditions and in hospitals</i> | <i>March 2010</i> | <i>IM2010, Athens</i> | <i>Scientific Community, Policy makers, Dosimetry community</i> | <i>400</i> | |
| 15 | <i>Presentation</i> | <i>L. Struelens</i> | <i>Use of Active personal dosemeters in interventional radiology/cardiology: tests in hospitals.</i> | <i>20-22 January 2011</i> | <i>ORAMED workshop Barcelona</i> | <i>Scientific Community, Policy makers, Medical staff</i> | <i>155</i> | <i>31 countries: 16 EC and 10 non EC European countries</i> |
| 16 | <i>Presentation</i> | <i>I. Clairand</i> | <i>Use of active personal dosemeters in interventional radiology/cardiology: tests with continuous and pulsed fields in laboratory conditions –ORAMED project</i> | <i>20-22 January 2011</i> | <i>ORAMED workshop Barcelona</i> | <i>Scientific Community, Policy makers, Medical staff</i> | <i>155</i> | <i>31 countries: 16 EC and 10 non EC European countries</i> |
| 17 | <i>Presentation</i> | <i>J. Daures</i> | <i>Guidelines on the use of active personal dosemeters in interventional radiology/cardiology</i> | <i>20-22 January 2011</i> | <i>ORAMED workshop Barcelona</i> | <i>Scientific Community, Policy makers, Medical staff</i> | <i>155</i> | <i>31 countries: 16 EC and 10 non EC European countries</i> |
| 18 | <i>Presentation</i> | <i>P. Martin</i> | <i>Proposals for Improvement of active personal dosimeters used in interventional radiology/cardiology</i> | <i>20-22 January 2011</i> | <i>ORAMED workshop Barcelona</i> | <i>Scientific Community, Policy makers, Medical staff</i> | <i>155</i> | <i>31 countries: 16 EC and 10 non EC European countries</i> |
| 19 | <i>Presentation</i> | <i>F. Vanhavere</i> | <i>The ORAMED project: optimization of radiation, protection for medical staff</i> | <i>March 2010</i> | <i>IM2010, Athens</i> | <i>Scientific Community, Policy makers, Dosimetry community</i> | <i>400</i> | |
| 20 | <i>Presentation</i> | <i>G. Gualdrini</i> | <i>Eye lens dosimetry: task 2 within the ORAMED project</i> | <i>March 2010</i> | <i>IM2010, Athens</i> | <i>Scientific Community, Policy</i> | <i>400</i> | |

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| | | | | | | makers, Dosimetry community | | |
| 21 | Presentation | G. Gualdrini | Eye-Lens Dosimetry – outcomes of the ORAMED Project | 20-22 January 2011 | ORAMED workshop Barcelona | Scientific Community, Policy makers, Medical staff | 155 | 31 countries: 16 EC and 10 non EC European countries |
| 22 | Presentation | J.M. Bordy | Proposal for Eye lens Dosemeter Calibration and Type Testing | 20-22 January 2011 | ORAMED workshop Barcelona | Scientific Community, Policy makers, Medical staff | 155 | 31 countries: 16 EC and 10 non EC European countries |
| 23 | Presentation | P. Bilski | A New Dosemeter for Measurements of Hp(3) for medical staff | 20-22 January 2011 | ORAMED workshop Barcelona | Scientific Community, Policy makers, Medical staff | 155 | 31 countries: 16 EC and 10 non EC European countries |
| 24 | Presentation | M. Sans Merce | Extremity exposure in nuclear medicine : preliminary results of a european study | March 2010 | IM2010, Athens | Scientific Community, Policy makers, Dosimetry community | 400 | |
| 25 | Presentation | A.Carnicer | The use of different types of thermoluminescent dosemeters to measure extremity doses in nuclear medicine | September 2010 | SSD, Sydney | Scientific Community, Dosimetry community | 300 | |
| 26 | Presentation | A.Rimpler | Extremity Exposure in Nuclear Medicine Therapy with 90Y labelled substances- Results of the ORAMED project. | 20-22 January 2011 | ORAMED workshop Barcelona | Scientific Community, Policy makers, Medical staff | 155 | 31 countries: 16 EC and 10 non EC European countries |
| 27 | Presentation | A.Carnicer | Extremity exposure in diagnostic nuclear medicine with 18F and 99mTc labelled | 20-22 January 2011 | ORAMED workshop Barcelona | Scientific Community, Policy makers, | 155 | 31 countries: 16 EC and 10 non EC European |

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|----|---------------------|----------------------|--|------------------------------|----------------------------------|---|------------|---|
| | | | <i>radiopharmaceuticals - Results of the ORAMED project</i> | | | <i>Medical staff</i> | | <i>countries</i> |
| 28 | <i>Presentation</i> | <i>M. Sans Merce</i> | <i>Recommendations to reduce hand exposure for standard nuclear medicine</i> | <i>20-22 January 2011</i> | <i>ORAMED workshop Barcelona</i> | <i>Scientific Community, Policy makers, Medical staff</i> | <i>155</i> | <i>31 countries: 16 EC and 10 non EC European countries</i> |
| 29 | <i>Presentation</i> | <i>F. Vanhavere</i> | <i>The ORAMED project: Optimization of Radiation Protection for Medical Staff”, oral presentation at the EURADOS General Assembly</i> | <i>29-01-2009</i> | <i>EURADOS GA Braunschweig</i> | <i>Dosimetry community</i> | <i>150</i> | |
| 30 | <i>Presentation</i> | <i>L. Struelens</i> | <i>The ORAMED project: “Optimization of Radiation Protection for Medical Staff”, oral presentation at the IAEA Technical meeting on the review of guidelines of occupational exposure of medical staff, IAEA</i> | <i>17-11-2008</i> | <i>IAEA meeting Vienna</i> | | | |
| 31 | <i>Presentation</i> | <i>M. Fülöp</i> | <i>Mapping hand dose by phantom measurements</i> | <i>October 11 – 14, 2008</i> | <i>EANM, Munich</i> | | | |
| 32 | <i>Presentation</i> | <i>J.M. Bordy</i> | <i>Implication du LNHB dans les contrats de recherche européens pour la dosimétrie des rayonnements ionisants en radiothérapie et en radioprotection</i> | <i>2008</i> | <i>SFPM, Marseille</i> | | | |
| 33 | <i>Presentation</i> | <i>I.Clairand</i> | <i>Use of active personal dosemeters in interventional radiology: a systematic study in laboratory conditions</i> | <i>September 2009</i> | <i>WC2009 Munich</i> | <i>Scientific Community, Policy makers, Medical community</i> | | |
| 34 | <i>Presentation</i> | <i>F. Vanhavere</i> | <i>The ORAMED project: Optimisation of Radiation Protection for Medical Staff</i> | <i>September 2009</i> | <i>WC2009 Munich</i> | <i>Scientific Community, Policy makers,</i> | | |

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|----|--------------|---------------|--|----------------------|---|--|-----|--|
| | | | | | | Medical community | | |
| 35 | Presentation | C. Koukorava | Extremity and eye lens doses of the staff during interventional radiology procedures – First results | September 2009 | WC2009 Munich | Scientific Community, Policy makers, Medical community | | |
| 36 | Presentation | M. Ginjaume | Optimizing Radiation Protection in Medical Practice | November 2009 | ETRAP 2009 Lisbon | | | |
| 37 | Presentation | M. Ginjaume | Hand dose distribution when handling radiopharmaceuticals in nuclear medicine | October 2009 | EANM, Barcelona | Scientific Community, Policy makers, Medical staff | 155 | 31 countries: 16 EC and 10 non EC European countries |
| 38 | Presentation | S. Krim | Optimisation of the extremity dosimetry in Nuclear Medicine | November 19, 2009 | MADEIRA course Malmo | | | |
| 39 | Presentation | M. Ginjaume | Participación española en el proyecto europeo sobre optimización de la protección radiológica del personal sanitario | June 2 till 5 2009 | SEFM Alicante | | | |
| 40 | Presentation | I.Barth | Strahlenexposition des Personals und Strahlenschutzmaßnahmen bei der Anwendung von Betastrahlern in der Nuklearmedizin | December 8 – 9, 2009 | Karlsruhe | | | |
| 41 | Presentation | D. Nikodemova | Radiation load of the extremities and eye lenses of the staff during interventional radiology procedures in Slovakia | November 2-6, 2009 | Days of radiation protection , Kouty Czech Republic | | | |
| 42 | Presentation | J.M. Bordy | References et perspectives en dosimetrie – Mesures opérationnelles en radioprotection dans les milieux industriel et médical | October 13, 2009 | SFRP, Paris | French Scientific Community, French Medical | | |

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| | | | | | | community | | |
| 43 | Presentation | I. Clairand | Optimisation de l'utilisation des dosimètres opérationnels en radiologie interventionnelle.- Les techniques interventionnelles en médecine et radioprotection | October 13, 2009 | SFRP, Paris | French Scientific Community, French Medical community | | |
| 44 | Presentation | S. Krim | Extremity dosimetry for medical staff during complex interventional procedures and in nuclear medicine | November 28, 2009 | NM Technologues Jette | | | |
| 45 | Presentation | S. Krim | Extremity dosimetry for medical staff during complex interventional procedures and in nuclear medicine | February 6-7, 2009 | BHPA, Kortrijk | | | |
| 46 | Presentation | S. Krim | Extremity dosimetry for medical staff during complex interventional procedures and in nuclear medicine | May 15-17,2009 | BSNM Bruges | | | |
| 47 | Presentation | G. Gualdrini | Il Progetto EU ORAMED: "Optimization of Radiation Protection for medical staff | September 16-19,2009 | AIFM, Reggio Emilia – Medical Physics Association Conference | Medical Physics Experts | 150 | Italian |
| | Presentation | P. Ferrari | Simulazioni numeriche in radiologia interventistica per il Work_package 1 del progetto ORAMED | September 16-19,2009 | AIFM, Reggio Emilia – Medical Physics Association Conference | Medical Physics Experts | 150 | Italian |
| 49 | Presentation | F. Mariotti | Progetto ORAMED: un nuovo approccio Monte Carlo per la definizione della grandezza operativa Hp(3) | September 16-19,2009 | AIFM, Reggio Emilia – Medical Physics Association Conference | Medical Physics Experts | 150 | Italian |

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|----|--------------|---------------|--|----------------------|---|--|-----|---------|
| 50 | Presentation | G. Gualdrini | Progetto ORAMED: "Optimization of Radiation Protection for medical staff | October 28-30,2009 | AIRP, Frascati (Rome) – Radiation Protection Association Conference | Radiation Protection Experts | 120 | Italian |
| 51 | Presentation | I.Clairand | Guidelines for the use of active personal dosimeters in interventional radiology | June 2010 | IRPA, Helsinki | Scientific Community, Policy makers | 600 | |
| 52 | Presentation | F. Vanhavere | Personal dosimetry for medical staff (the ORAMED project) | April 25, 2010 | NVS Iustrum Scheveningen | | 150 | |
| 53 | Presentation | N. Ruiz Lopez | The ORAMED project: Optimisation of Radiation Protection for Medical Staff in Interventional Radiology, Cardiology and Nuclear Medicine | November 9-12, 2010 | IDOS, Vienna | | 500 | |
| 54 | Presentation | M. Ginjaume | | September 1-3, 2010 | International Conference on Radiation Protection Varna | | | |
| 55 | Presentation | M. Sans Merce | Radiation Exposure to staff | November 15-19, 2010 | EANM, Vienna | | | |
| 56 | Presentation | P.Ferrari | Dosimetria delle estremità e del cristallino in radiologia e cardiologia interventistica: Il progetto EU-ORAMED | 27-29 October 2010 | XV National Conference of Italian Radiation research Society | Scientific Community, | 70 | Italy |
| 57 | Presentation | P.Ferrari | Studi dosimetrici in medicina nucleare: il contributo italiano al progetto ORAMED. | 15-17 December 2010 | Radiation protection Association Conference | Radiation protection experts | 120 | Italy |
| 58 | Presentation | A.Rimpler | Teilkörperexpositionen des personals bei nuklearmedizinischen therapien mit Y-90 markierten radiopharmaka – | | Annual Congress of german, Austrian and Swiss | | | |

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| | | | <i>ergebnisse des EU-Projekts ORAMED</i> | | <i>societies of Nuclear Medicine</i> | | | |
| 59 | <i>Presentation</i> | <i>M. Ginjaume</i> | <i>Improving standards of Radiation Protection in Medical Practice</i> | <i>May 30 till June 2, 2010</i> | <i>ENC, Barcelona</i> | | | |
| 60 | <i>Presentation</i> | <i>P. Ferrari</i> | <i>Challenges on the radiation protection optimization of medical staff in interventional radiology and nuclear medicine: the ORAMED project</i> | <i>June 2010</i> | <i>IRPA, Helsinki</i> | | | |
| 61 | <i>Presentation</i> | <i>C. Koukorava</i> | <i>Optimization of Radiation Protection for Medical Staff – The ORAMED project</i> | <i>September 1-3, 2010</i> | <i>International Conference on Radiation Protection Varna</i> | | | |
| 81 | <i>Paper presented</i> | <i>F. Vanhavere</i> | <i>Occupational Exposure of Medical Staff: An Overview</i> | <i>February 7-9, 2011</i> | <i>EURADOS GA Prague</i> | <i>Dosimetry community</i> | <i>150</i> | |
| 82 | <i>Paper presented</i> | <i>E. Carinou</i> | <i>Extremity dosimetry and Eye Lens dosimetry in interventional radiology</i> | <i>February 7-9, 2011</i> | <i>EURADOS GA Prague</i> | <i>Dosimetry community</i> | <i>150</i> | |
| 83 | <i>Paper presented</i> | <i>G. Gualdrini</i> | <i>Development of Practical eye lens dosimetry</i> | <i>February 7-9, 2011</i> | <i>EURADOS GA Prague</i> | <i>Dosimetry community</i> | <i>150</i> | |
| 84 | <i>Paper presented</i> | <i>I. Clairand</i> | <i>The use of active personal doseimeters in interventional radiology</i> | <i>February 7-9, 2011</i> | <i>EURADOS GA Prague</i> | <i>Dosimetry community</i> | <i>150</i> | |
| 85 | <i>Paper presented</i> | <i>M. Sans Merce</i> | <i>Extremity Dosimetry in nuclear Medicine.</i> | <i>February 7-9, 2011</i> | <i>EURADOS GA Prague</i> | <i>Dosimetry community</i> | <i>150</i> | |
| 86 | <i>Presentation</i> | <i>E. Carinou</i> | <i>ORAMED measurement and simulation campaign for extremity and eye lens doses of medical staff involved in interventional radiology and cardiology</i> | <i>20-22 January 2011</i> | <i>ORAMED workshop Barcelona</i> | <i>Scientific Community, Policy makers, Medical staff</i> | <i>155</i> | <i>31 countries: 16 EC and 10 non EC European countries</i> |
| 86 | <i>Presentation</i> | <i>P. Ferrari</i> | <i>Main results of the Monte Carlo studies carried out for nuclear medicine practices within the ORAMED project</i> | <i>20-22 January 2011</i> | <i>ORAMED workshop Barcelona</i> | <i>Scientific Community, Policy makers, Medical staff</i> | <i>155</i> | <i>31 countries: 16 EC and 10 non EC European countries</i> |

Section B (Confidential¹ or public: confidential information to be marked clearly)
Part B1

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable, contributions to standards should be specified. This table is cumulative, which means that it should always show all applications from the beginning until after the end of the project.

| TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC. | | | | | |
|--|------------------------------------|--|--|---------------------------------|---------------------------------------|
| Type of IP Rights ² : | Confidential Click on YES/NO | Foreseen embargo date dd/mm/yyyy | Application reference(s) (e.g. EP123456) | Subject or title of application | Applicant (s) (as on the application) |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

¹ Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.

² A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

Please complete the table hereafter:

| Type of Exploitable Foreground ³ | Description of exploitable foreground | Confidential Click on YES/NO | Foreseen embargo date dd/mm/yyyy | Exploitable product(s) or measure(s) | Sector(s) of application ⁴ | Timetable, commercial or any other use | Patents or other IPR exploitation (licences) | Owner & Other Beneficiary(s) involved |
|---|---------------------------------------|------------------------------|----------------------------------|--------------------------------------|---------------------------------------|--|--|---------------------------------------|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

In addition to the table, please provide a text to explain the exploitable foreground, in particular:

- Its purpose
- How the foreground might be exploited, when and by whom
- IPR exploitable measures taken or intended
- Further research necessary, if any
- Potential/expected impact (quantify where possible)

¹⁹ A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

⁴ A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

4.3 Report on societal implications

| A General Information | |
|---|---|
| Grant Agreement Number: | 211361 |
| Title of Project: | ORAMED: Optimization of Radiation Protection of Medical Staff |
| Name and Title of Coordinator: | Dr. Ir. Filip Vanhavere |
| B Ethics | |
| 1. Did your project undergo an Ethics Review (and/or Screening)? <ul style="list-style-type: none"> • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? <p>Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 'Work Progress and Achievements'</p> | No <i>0Yes 0No</i> |
| 2. Please indicate whether your project involved any of the following issues (tick box) : | YES |
| RESEARCH ON HUMANS | |
| • Did the project involve children? | No |
| • Did the project involve patients? | No |
| • Did the project involve persons not able to give consent? | No |
| • Did the project involve adult healthy volunteers? | Yes |
| • Did the project involve Human genetic material? | No |
| • Did the project involve Human biological samples? | No |
| • Did the project involve Human data collection? | No |
| RESEARCH ON HUMAN EMBRYO/FOETUS | |
| • Did the project involve Human Embryos? | No |
| • Did the project involve Human Foetal Tissue / Cells? | No |
| • Did the project involve Human Embryonic Stem Cells (hESCs)? | No |
| • Did the project on human Embryonic Stem Cells involve cells in culture? | No |
| • Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos? | No |
| PRIVACY | |
| • Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)? | No |
| • Did the project involve tracking the location or observation of people? | No |
| RESEARCH ON ANIMALS | |
| • Did the project involve research on animals? | No |
| • Were those animals transgenic small laboratory animals? | No |
| • Were those animals transgenic farm animals? | No |
| • Were those animals cloned farm animals? | No |
| • Were those animals non-human primates? | No |
| RESEARCH INVOLVING DEVELOPING COUNTRIES | |
| • Did the project involve the use of local resources (genetic, animal, plant etc)? | No |
| • Was the project of benefit to local community (capacity building, access to healthcare, education etc)? | No |
| DUAL USE | |
| • Research having direct military use | No |
| • Research having the potential for terrorist abuse | No |

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

| Type of Position | Number of Women | Number of Men |
|--|-----------------|---------------|
| Scientific Coordinator | | 1 |
| Work package leaders | 4 | 1 |
| Experienced researchers (i.e. PhD holders) | 12 | 15 |
| PhD Students | 3 | 1 |
| Other | 1 | 3 |

4. How many additional researchers (in companies and universities) were recruited specifically for this project?

4

Of which, indicate the number of men:

1

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project? Yes
 No

6. Which of the following actions did you carry out and how effective were they?

| | Not at all effective | Very effective |
|---|---|---|
| <input type="checkbox"/> Design and implement an equal opportunity policy | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> |
| <input type="checkbox"/> Set targets to achieve a gender balance in the workforce | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> |
| <input type="checkbox"/> Organise conferences and workshops on gender | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> |
| <input type="checkbox"/> Actions to improve work-life balance | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> |
| <input type="radio"/> Other: <input type="text"/> | | |

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

Yes- please specify

No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

Yes- please specify

No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

Yes- please specify

Training material (presentations),
video, dose estimation tool, guidelines

No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

Main discipline: 1.2

Associated discipline:

Associated discipline:

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? (if 'No', go to Question 14) Yes
 No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

No

Yes- in determining what research should be performed

Yes - in implementing the research

Yes, in communicating /disseminating / using the results of the project

| | | |
|--|---|---|
| 11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)? | <input type="radio"/> <input checked="" type="radio"/> | Yes No |
| 12. Did you engage with government / public bodies or policy makers (including international organisations) | | |
| <input type="radio"/> No <input type="radio"/> Yes- in framing the research agenda <input type="radio"/> Yes - in implementing the research agenda <input checked="" type="radio"/> Yes, in communicating /disseminating / using the results of the project | | |
| 13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers? <input checked="" type="radio"/> Yes – as a primary objective (please indicate areas below- multiple answers possible) <input type="radio"/> Yes – as a secondary objective (please indicate areas below - multiple answer possible) <input type="radio"/> No | | |
| 13b If Yes, in which fields? | | |
| Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs | Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid | Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport |
| | | X |

| | | |
|--|---|----------|
| 13c If Yes, at which level? <input type="radio"/> Local / regional levels <input type="radio"/> National level <input type="radio"/> European level <input checked="" type="radio"/> International level | | |
| H Use and dissemination | | |
| 14. How many Articles were published/accepted for publication in peer-reviewed journals? | 11 | |
| To how many of these is open access⁵ provided? | 0 | |
| How many of these are published in open access journals? | 0 | |
| How many of these are published in open repositories? | 0 | |
| To how many of these is open access not provided? | 11 | |
| Please check all applicable reasons for not providing open access: | | |
| <input checked="" type="checkbox"/> publisher's licensing agreement would not permit publishing in a repository <input type="checkbox"/> no suitable repository available <input checked="" type="checkbox"/> no suitable open access journal available <input type="checkbox"/> no funds available to publish in an open access journal <input type="checkbox"/> lack of time and resources <input type="checkbox"/> lack of information on open access <input type="checkbox"/> other ⁶ : | | |
| 15. How many new patent applications ('priority filings') have been made? <i>("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).</i> | 0 | |
| 16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box). | Trademark | 0 |
| | Registered design | 0 |
| | Other | 0 |
| 17. How many spin-off companies were created / are planned as a direct result of the project? | None | |
| <i>Indicate the approximate number of additional jobs in these companies:</i> | | |
| 18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project: | | |
| <input type="checkbox"/> Increase in employment, or <input type="checkbox"/> Safeguard employment, or <input type="checkbox"/> Decrease in employment, <input checked="" type="checkbox"/> Difficult to estimate / not possible to quantify | <input type="checkbox"/> In small & medium-sized enterprises <input type="checkbox"/> In large companies <input type="checkbox"/> None of the above / not relevant to the project | |
| 19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (FTE = one person working fulltime for a year) jobs: | <i>Indicate figure:</i> | |

⁵ Open Access is defined as free of charge access for anyone via Internet.

⁶ For instance: classification for security project.

| | | |
|---|--|---|
| Difficult to estimate / not possible to quantify | | X |
| I Media and Communication to the general public | | |
| 20. As part of the project, were any of the beneficiaries professionals in communication or media relations? | | |
| <input type="radio"/> Yes <input checked="" type="radio"/> No | | |
| 21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public? | | |
| <input type="radio"/> Yes <input checked="" type="radio"/> No | | |
| 22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project? | | |
| <input type="checkbox"/> Press Release <input type="checkbox"/> Media briefing <input type="checkbox"/> TV coverage / report <input type="checkbox"/> Radio coverage / report <input checked="" type="checkbox"/> Brochures /posters / flyers <input type="checkbox"/> DVD /Film /Multimedia | <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> | Coverage in specialist press Coverage in general (non-specialist) press Coverage in national press Coverage in international press Website for the general public / internet Event targeting general public (festival, conference, exhibition, science café) |
| 23 In which languages are the information products for the general public produced? | | |
| <input type="checkbox"/> Language of the coordinator <input checked="" type="checkbox"/> Other language(s) | <input checked="" type="checkbox"/> | English |

Question F-10: Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

- 1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]
- 1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)
- 1.3 Chemical sciences (chemistry, other allied subjects)
- 1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)
- 1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2. ENGINEERING AND TECHNOLOGY

- 2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)
- 2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]
- 2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as

geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

- 3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immuno-haematology, clinical chemistry, clinical microbiology, pathology)
- 3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)
- 3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

- 4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)
- 4.2 Veterinary medicine

5. SOCIAL SCIENCES

- 5.1 Psychology
- 5.2 Economics
- 5.3 Educational sciences (education and training and other allied subjects)
- 5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary, methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

- 6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)
- 6.2 Languages and literature (ancient and modern)
- 6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]