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Editorial

The International Commission on Radiological Protection (ICRP) introduced the concept of existing exposure situations in Publication 103 (2007). Existing exposure situations are defined as:

> *"situations of exposure that already exist when a decision on control has to be taken".*

For example, radon exposure and cosmic radiation exposure in aviation both fulfill the ICRP definition.

The optimisation principle applies in existing exposure situations to keep the likelihood of incurring exposures, the number of people exposed and the magnitude of individual exposure as low as reasonably achievable (ALARA).

However, it is recognised that many factors can influence the application of the ALARA principle when it comes to existing exposure situations (see for example the conclusions of EAN workshop n°14). Individual behaviour, local circumstances, stakeholder awareness and involvement may also shape and influence the implementation of ALARA.

In this issue of the EAN Newsletter, two approaches to the management of radon exposure are reported: a voluntary project initiated in the Pays de Montebeliard Agglomération (France), and the implementation of a National Radon Control Strategy in Ireland. It is fruitful to compare the framework, tools and outcomes of these action plans.
The situation of exposure in the stratosphere is also explored with the presentation of aircraft crew cosmic radiation exposure data for 9 European countries over the period 2009-2014. The different factors that may influence crew exposures are analysed and discussed.

Please also remember that the EAN is planning its 17th workshop on the implementation of ALARA in emergency exposure situations (15-17th May 2017, Portugal). For more information about programme content and registration, you can visit the registration website:
http://www.planetreg.com/EANworkshop17NERISworkshop3

Sylvain Andresz, for the Editorial Board

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Management of Radon Risk in Pays de Montbéliard Agglomération (France)

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Introduction

Based on radon measurements and geological data, 31 French departments are classed as "radon priority department" and subject to regulation under the 22nd July 2004 Decree. This Decree only applies for the management of radon in public buildings (existing and new educational, thermal spa and prison establishments etc). The regulatory requirements are listed in Table 1 below.

The concentration of 400 Bq.m-3 can be seen as a "reference level" whereas 1000 Bq.m-3 is the "action level". There are no regulatory requirements placed on departments not labelled as "radon priority department".

This regulation is currently under review following the implementation of Euratom Directive 2013/59. The key expected changes are the modification of the list of "radon priority departments" (a list at communal level will be provided), and the lowering of the reference level to 300 Bq.m-3. It will also be a requirement for information on radon risk to be given during property transactions.

Concentration of radon	Requirements
Below 400 Bq.m-3	• No action required
Between 400 and 1,000 Bq.m-3	• Simple remediation (venting and/or sealing) • Efficiency control
Above 1,000 Bq.m-3or still above 400 Bq. m-3 after simple remediation	• Technical diagnosis of the building • Remediation work within two years • Efficiency control

Table 1. – Regulatory requirements for French public buildings under the 22nd July 2004 Decree.

The Montbéliard Radiation Protection Project

The Montbéliard Community of Municipalities – PMA in French – belongs to the Doubs department, which is classed as a 'radon priority department'. PMA is composed of 29 municipalities, from village to town. Since the 1st January 2017, and following major changes in France's administrative map, 42 villages have joined the Community. The Community is in charge of some aspects of economic, social, environment, health, education etc.

In 2004, PMA initiated the Montbéliard Radiation Protection Project, with the following objectives to:

- improve the radiation protection of the inhabitants;
- create a centre of competence in the field of radiation protection; and
- develop radiation protection culture among the inhabitants.

In this framework, four components have been identified:

- radon and medical exposures
- emergency preparedness
- education and training
- scientific and technical culture

To set up the project, large extended partnerships were developed with a wide range of stakeholders from local, national and international levels to include: University of Bourgogne/ Franche-Comté, Regional Health Agency, Nuclear Safety Authority, French Institute for Radiological Protection and Nuclear Safety, and in Switzerland the Federal Office of Public Health (FOPH), the School of Engineering and Architecture of Fribourg (HEIA-FR), etc. The Nuclear Evaluation Protection Centre – CEPN (France) - acts as facilitator of the project.

With an estimated average indoor radon concentration of 180 Bq.m-3, the Pays de Montbéliard is considered as a "radon priority department". In this context, PMA has engaged various actions to reduce radon exposure and maintain ALARA in the Community.

Radon in dwellings

In 2005, PMA launched an awareness campaign on radon risk for inhabitants of the Community as part of a general "Housing Improvement Programme" set up in the Region. During winter 2006-2007, several elected representatives met to set up a radon management organisation. Public information meetings on radon risk were organised to identify volunteer inhabitants. The measurement campaign was performed by public hygiene officers in 350 private dwellings and received clear support from the elected representatives of the 29 municipalities of the Community. The results of these measurements were presented to the inhabitants by the Mayors. The Community decided to financially support inhabitants with radon concentrations above 300 Bq.m-3 in their homes. Swiss radon consultants performed radon surveys; the costs were covered by PMA.

After this first campaign, PMA wanted to give individuals the tools to measure radon concentrations in their own homes. Following a communication campaign, passive radon dosimeters were distributed free of charge to volunteer inhabitants. Similar campaigns were repeated at regular intervals and, since 2007, about 900 inhabitants have measured the radon concentrations in their domestic dwellings.

PMA had difficulty in finding appropriate local expertise to investigate and carry out remediation works for inhabitants with radon concentration > 300 Bq.m-3 in their homes. Under this framework, PMA developed partnerships with regional and national stakeholders and particularly with the Center for Studies and Expertise on Risks, Environment, Mobility and Development (CEREMA).

Radon in public buildings

To comply with the 22nd July 2004 Decree (related to measurements of radon concentration in public buildings) the Community decided to initiate a measurement campaign in schools. The first step was to search for an organisation certified to carry out radon measurements (as required by the regulations). Due to the absence of such organisation at regional level and the high cost associated with dealing with national certified organisations, PMA decided to apply for certification of its public hygiene office. Five officers were trained. Since 2008 (when the Community obtained certification) all schools and kindergartens have been measured; which is approximately 250 public buildings.

Data analysis

The radon campaigns set up since 2007 resulted in measurement of more than 1,200 buildings (private dwellings and public buildings). This is equivalent to 1 building out of 43 in the Pays of Montbéliard being tested. Figure 1 shows that about 50% of the buildings tested have radon concentrations below 100 Bq.m-3. 10% of buildings show radon concentrations over the future national reference level of 300 Bq.m-3 and 1% above 1,000 Bq.m-3.

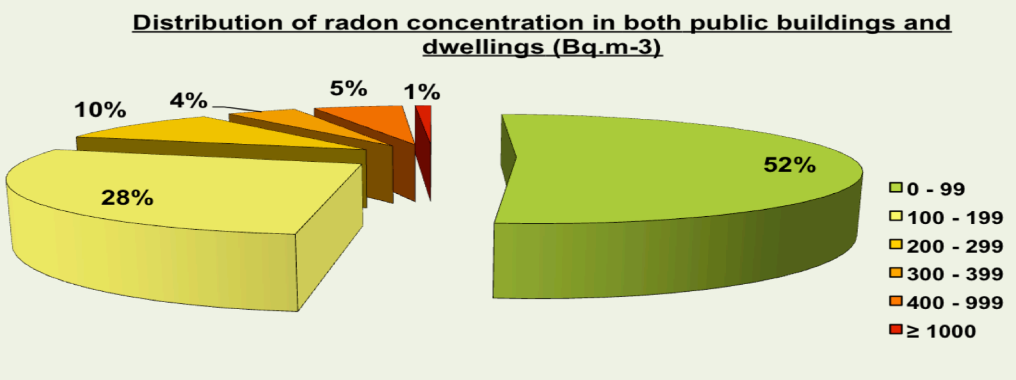

Figure 1. – Distribution of radon concentration in the Pays of Montbéliard (public buildings and dwellings)

Geological mapping

Radon measurements for each building have been integrated with a Geographic Information System and associated with a geologic map in order to examine the spatial and statistical associations between radon values and geological bedrock. Rock types in the area are sedimentary and typically include limestone, silt, clay or marl.
Figure 2 shows that two geological formations stand out significantly from the others: alluvium

and limestone. Average radon concentrations in buildings located over these two geological formations are clearly higher than for other geological formations.
If the year of construction is considered, Figure 3 illustrates that higher radon concentrations are more likely to be found in older buildings.

Figure 4 shows that an efficient and adapted ventilation system assists in reducing radon concentrations. Indeed, without air intake, radon concentration is significantly higher than in buildings with a double-flow mechanical ventilation system.

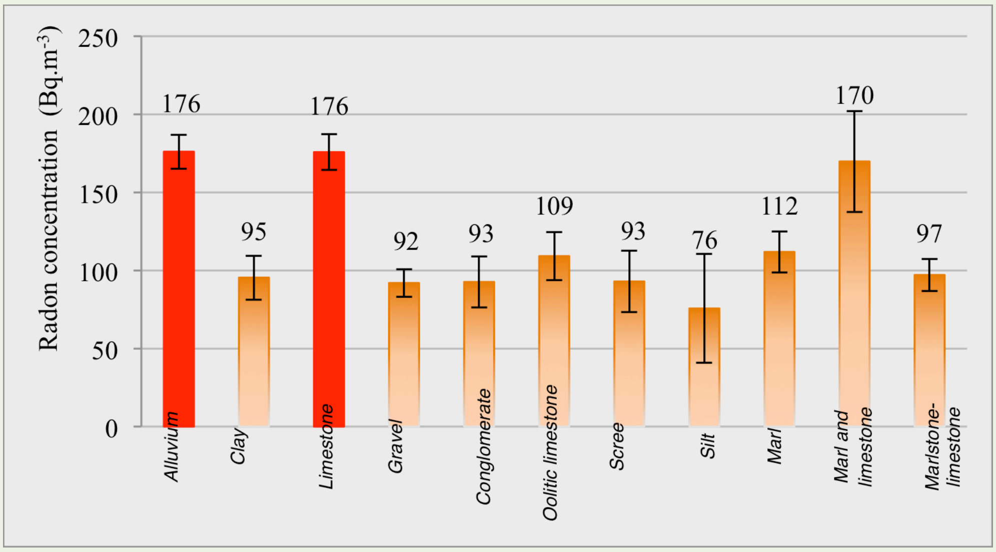

Figure 2. – Average radon concentration in buildings according to underlying geological formations.

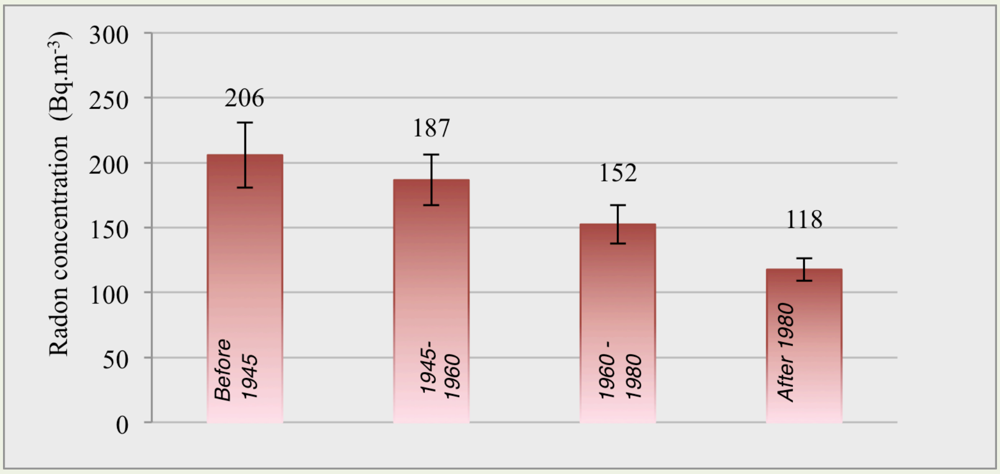

Figure 3. – Average radon concentration according to construction year.

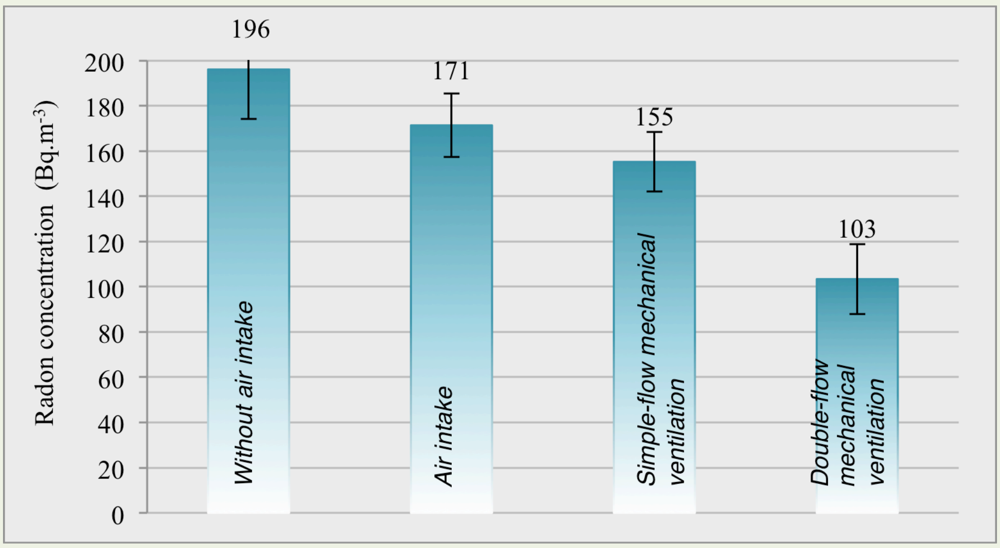

Figure 4. – Average radon concentration according to indoor air system.

Lessons learned

- Awareness campaigns and actions of health officers in the Community are welcomed by inhabitants and do not raise concerns contrary to fears expressed by some national experts and local elected representatives before starting the project.
- There are difficulties in finding local expertise to carry out radon surveys and remediation works. There is an obvious need to develop a local competence among building companies for these two crucial steps in the management of radon exposure.
- It is also essential to develop a synergy between the management of radon, indoor air quality and energy performance of buildings, to help promote the sustainable commitment of residents.
- Ensuring radon exposures are ALARA is a long-term process.

Future work

Following on from fruitful exchanges with Switzerland in the course of this work, and the common issue of radon risk in the Jurassian Arc (karstic region), the Montbéliard Community of Municipalities initiated with the School of Engineering and Architecture of Fribourg and 21 other partners (Federal Office of Public Health, University of Bourgogne - Franche-Comté, Building professionals representatives, etc.) an Interreg France Switzerland Project 'JURAD-BAT' to improve the management of radon exposure. The objective of this three year project, launched in September 2016, is to develop a database and web platform for stakeholders in charge of radon risk, management of indoor air quality and energy performance of buildings. This platform will contain decision-making tools like training courses, awareness documents, etc. Furthermore, all data gathered on the study area of the Jurassian Arc will enable further correlation analysis of radon concentration and factors such as indoor air quality and building features (ventilation system, ground level, class of energy, etc.) ❏

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Implementation of the National Radon Control Strategy for Ireland: Year 2 of the Strategy (April 2015 to June 2016)

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Introduction and background

Radon is a naturally occurring radioactive gas formed in the ground by the radioactive decay of uranium which is present in all rocks and soils. It is the greatest source of exposure to ionising radiation for the general public in Ireland and the leading cause of lung cancer after smoking. It is estimated that exposure to radon accounts for approximately 13% of all lung cancers in Ireland, which equates to some 250 lung cancer cases each year.

Recognising the scale of the radon problem in Ireland, the Government published the National Radon Control Strategy (NRCS) in February 2014 (Summary of Actions attached at Annex 1). Moreover, it was recognised that implementation of the NRCS would meet the requirement for a radon action plan as set out in Article 103 of Council Directive 2013/59/Euratom, Basic Safety Standards Directive (BSS). The NRCS is supported by the Department of Communications, Climate Action and the Environment (DCCAE) in their Statement of Strategy 2015 to 2017 under the goal "Protecting Our Environment".

Successful implementation of the NRCS requires action from a range of Government Departments, public bodies and other stakeholders and clear identification of responsibilities, good co-ordination between the various stakeholders and effective monitoring of progress. Accordingly, a NRCS Co-ordination Group was established in 2014, led by the DCCAE and comprises representatives from key Departments and Agencies, to implement and track the key recommendations in the Strategy over its four year lifetime. Membership of the Co-ordination Group and Steering Groups is listed in Annex 2.

The primary objectives of the Co-ordination Group are to:

- act as a point of contact between all bodies with responsibility for delivery of the Strategy;
- develop an annual work plan consistent with delivery of the overall Strategy;
- monitor the implementation of the Strategy against both the annual work plan and overall progress on the Strategy recommendations;
- report annually to Government;
- identify issues or difficulties in relation to any of the Strategy's recommendations as they arise and seek to facilitate resolution as appropriate;
- put in place arrangements to ensure that the effectiveness of the plan is assessed at appropriate intervals; and
- at the end of the 4-year period, make recommendations to Government on what further actions, if any, the Group considers necessary at that time.

Year Two Progress (April 2015 to June 2016)

The Strategy contains recommendations on a broad range of measures aimed at reducing the risk from radon to people living in Ireland. These are set out in six thematic areas as follows:

- Installation of passive preventive measures in new buildings;
- Use of property transactions (sales and rental) to drive action on radon;
- Raising of radon awareness and encouraging individual action on radon;
- Provision of advice and guidance for individual householders and employers with high radon readings;
- Promoting confidence in radon services; and
- Addressing radon in workplaces and public buildings.

Work is on-going across all six thematic areas and good progress has been made on the implementation of the NRCS action plan. There are 30 actions set out in the NRCS (listed at Annex 1) and three Steering Groups have been established to progress specific actions. At this half-way point, work is on-going on 23 of the 30 identified action points. Of these 23 actions, 5 are complete with a further 8 on track for completion in Year 3. The following provides some detail on progress made on several priority actions:

Action 2: *Develop a dedicated Radon website*
The design, content and domain name for the website have been agreed and developed. The website (www.radon.ie) is now live and was formally launched in October 2016 at Ireland's national radon forum.

Action 3: *Establish a Co-ordination Group to oversee and co-ordinate implementation of the NRCS.*
The established Co-ordination Group has agreed on a suite of metrics to enable measurement of the impact of the actions developed and implemented against the objective of the strategy to reduce the number of radon related lung cancers in Ireland.

Action 6: *Develop short targeted training course for site staff on radon prevention.*
This course has been developed but will be augmented with a video to enhance the more practical aspects of the site work. It will be piloted in 2016 for roll out in 2017 by the Construction Industry Federation as part of their suite of courses.

Action 9 & 11: *Promote targeted research on radon to support effective and efficient implementation of the NRCS.*
Calls for research to address particular knowledge gaps identified during the development of the NRCS were included in the EPA 2015 research call. This has resulted in the EPA funding two research projects:

1. An investigation of optimal specifications for the installation of radon preventive measures in Irish buildings. This is a three year project that will be carried out by researchers in NUI Galway and Spanish colleagues. Work on this project has begun.

2. An investigation to better understand ventilation and radon in energy efficient buildings in Ireland. This is a one year project that will be carried out by another group of researchers in NUI Galway. Work on this project has begun.

Additional research in support of the NRCS completed by the EPA during this period includes a study of radon remediation rates among homeowners living in homes with radon levels above the Reference Level of 200 Bq/m3 and an update of the radon levels and building type.

Action 10: *Update the national assessment of indoor radon levels.*
This research was completed during 2016 and shows that the implementation of Building Regulations since 1998, to address radon, combined with other measures has resulted in a reduction in the national average indoor radon level from 89 Bq/m3 to 77 Bq/m3. This represents a 13% reduction in the average level of exposure of the Irish population to radon.

Action 12: *Implement multi-annual programme of local radon awareness campaigns.*
There are twelve priority counties (i.e. with above average radon levels) and by the end of 2016, awareness campaigns will have been carried out in all twelve of these counties since March 2010.

During 2015 a review of these campaigns was carried out from the perspective of Health Psychology. This review concluded that "*the awareness campaigns are broadly comparable to similar multi-media community education programmes in content and process, follow the best practice guidelines for radon risk communication and their level of impact on radon testing and remediation is comparable to those reported in the peer-reviewed empirical literature*".

However, the review pointed out that "*the extent to which awareness programmes can address these gaps to change behaviour remains unclear – the programmes can provide knowledge but … such information may not translate into behaviour in the face of psycho-social and financial barriers to action*". The review advises that the State has an important role to play in managing the risk from radon and that increased governmental regulation, supported by financial incentives, combined with high quality information programmes are required to significantly increase the rate of testing and remediation.

This report has been published by the EPA.

The conclusions of this review have formed an important input into the development of a national communication strategy (see Action 13).

A new programme of awareness raising for priority counties will be piloted during 2016 (see Action 13).

Action 13: *Development and implementation of a national communication strategy.*
A national strategy has been developed and agreed by the Co-ordination Group. This strategy integrates communications and advocacy actions to promote awareness and behavioural change regarding radon. Certain actions under the strategy will be piloted during 2016 and baseline metrics data captured, with the intention of fully rolling out the strategy in 2017.

Action 16: *Develop guidelines for local authorities on dealing with requests for information on radon*
The radon website (see Action 2) includes advice and guidance for local authorities and other housing agencies. The radon remediation training course (see Action 23) was attended by Local Authority engineers and technicians.

Action 19: *Develop a detailed strategy to progress recommendations on conveyancing*
An agreement has been reached between DCCAE, the Law Society and the Society of Chartered Surveyors of Ireland that three questions related to radon will be included in the non-title information sheet.

Action 22: *Develop a paper on financial incentives to encourage action on radon.*
Cost has long been identified as a disincentive to householders to test and remediate their homes. Further consideration on how best to implement this action will be given by DCCAE and the Co-Ordination committee.

Action 23: *Develop a framework for training in radon remediation.*
The training course has been developed, piloted and rolled out by the Radon Remediation Steering Group, facilitated by the Local Authority National Training Services Group at four national centres in May of 2016. A total of 89 Local Authority engineers and technicians, staff of government bodies such as the OPW and HSE along with radon remediation contractors attended this course.

Action 25: *Develop criteria which remediation contractors must meet in order to be included on any Government list or website.*
These criteria will be developed and a registration scheme rolled out in 2016.

Action 26: *Develop registration scheme for radon measurement services in Ireland.*
The format of the registration scheme has been agreed. The scheme will be rolled out in 2016.

Action 30: *Develop guidance on the need for retesting of previously remediated buildings.*
Studies carried out by the HSE and TCD of schools that had previously tested high and were consequently remediated have highlighted the importance of maintenance of remediation systems and the need for retesting following building or refurbishment work. The outcome of this work will form an important input to the development of guidance regarding maintenance and retesting. Work has commenced with the Department of Education and Skills to determine what actions could be delivered under the NRCS to support school Principals and Boards of Management regarding the maintenance of remediation systems in schools. It should be noted that all new schools are fitted with a radon barrier during construction and tested for radon within five months of completion.

New Action: *Radon in crèches.*
Following the work in schools the need to consider radon exposure in crèches has come to the fore. The EPA has engaged bilaterally with TUSLA (the State agency responsible for improving wellbeing and outcomes for children) on how best to increase awareness and promote action amongst relevant agencies and crèche owners.

Supporting the NRCS Co-ordination Group, three Steering Groups (further details at Annex 2) were established to drive forward consideration of specific elements with a view to providing further analysis and proposed recommendations back to the Co-ordination Group for consideration and action:

Planned Actions for Year Three

Building on the progress outlined above, the Co-ordination Group agreed that the following actions be prioritised and further progressed during 2016 and early 2017:

1. Promote awareness of the dedicated radon website. (Action 2)
2. Establish baseline metrics to measure the impact of actions implemented. (Action 3)
3. Make recommendations to DCCAE on the amendment and strengthening of technical guidance on radon prevention in new buildings. (Action 4)
4. Consideration to be given on whether radon can be included as a sign-off measure as part of an ancillary certificate within Building Control (Amendment) Regulations 2013. (Action 5)
5. Pilot and rollout short targeted training for building site staff on radon prevention with the cooperation of Construction Industry Federation. (Action 6)
6. Improve the existing radon risk map as a public communications tool in collaboration with the GSI. (Action 9)
7. Research on the optimal techniques for radon preventive and remediation measures is on-going. (Action 9 and 11)
8. Research on radon in energy efficient buildings in Ireland is on-going. (Action 9)
9. Publish results of research on home remediation rates, the effectiveness of the building regulations on radon levels and the impact of building characteristics on radon levels. (Action 9)
10. Publish the results of the assessment of indoor radon levels. (Action 10)
11. Establish the revised population weighted, mean indoor radon level, as an indicator of the annual number of radon related lung cancer deaths in Ireland. This updated figure will serve as an index of the health impact of indoor radon reduction in Ireland as well as being a baseline for the NRCS action plan. (Action 10)
12. Pilot a revised national communications campaign in Co. Wicklow (Actions 12 and 13)
13. Rollout of the national communications strategy. (Action 13)
14. The revised text for the BER Advisory Report to include advice on radon. Revised text to be finalised during 2016. Final approval of text by DECLG and Minister. (Action 18).
15. Monitor implementation of the decision to include radon in the conveyancing process. (Action 19)
16. Input to the 2016 review of Housing (Standards for Rented Houses) Regulations. (Action 20)
17. Develop details and implementation plans for the scheme of financial incentives to encourage action on radon. (Action 22)
18. Develop criteria which radon remediation contractors must meet in order to be included on a Government list or website. Rollout registration scheme (Action 25)
19. Develop a registration scheme for radon measurement services. (Action 26)
20. Develop guidance on maintenance and retesting previously remediated buildings in conjunction with the Department of Education and Skills. (Action 30)
21. Work with TUSLA to develop a training course for those with responsibility for radon in crèches. (new Action)

Summary of key highlights for 2016 and planned actions for Year Three of Ireland's NRCS

Key Highlights for Year Two:

Of the 30 actions set out in the National Radon Control Strategy (NRCS):

- 5 actions are complete
- 8 actions are on track for completion in Year 3
- Work has commenced on a further 10 actions

Key achievements during 2015/16 include:

- Agreement between the Law Society of Ireland, the Society of Chartered Surveyors of Ireland and the DECLG to include three questions regarding radon in the conveyancing process
- Completion of the dedicated radon website www.radon.ie
- Development of a national communications strategy
- Development of a training course in radon preventive measures
- Development, piloting and rollout of a training course in radon remediation methods
- Research showing that the average radon level in Ireland has reduced by 13% from 89 Bq/m3 to 77 Bq/m3 since the introduction of the Building Regulations in 1998.

Key Challenges for Year Three

- Establishing drivers for action on radon
  Research carried out under the NRCS has shown that further information campaigns aimed at raising awareness of the risks from radon will not necessarily result in an increase in the number of homes that test for radon. It has been advised that regulatory approaches, supported by financial incentives, combined with high quality information programmes are required to increase the rate of testing and remediation and improve health outcomes.

  A key challenge will be to maximize opportunities for regulatory drivers of action to address radon.

- Maximising the potential of conveyancing to promote radon testing
  Including radon questions in the conveyancing process, while not a regulatory requirement as such, has been shown to be a powerful driver of action on radon. In this context, monitoring implementation of the decision to include radon in the conveyancing process will be a key task for Year Three.
- Supporting householders with the cost of radon work
  The implementation of schemes that offer financial assistance to homeowners for radon testing and remediation will be a critical task in ensuring the effectiveness of the National Radon Control Strategy. ❑

Annex 1 – Summary NRCS Action Plan to June 2016

No.	Action	Status
1	Develop a branding strategy and communications programme for the launch of the NRCS	Complete
2	Develop a dedicated radon website as resource for stakeholder groups	Complete
3	Establish a co-ordination group comprising key public bodies to oversee and co-ordinate implementation of the NRCS	Complete
4	Make recommendations to DECLG on the amendment and strengthening of technical guidance on radon prevention in new buildings	On target for completion in 2016
5	Promote radon as a sign off measure within the Building Control (Amendment) Regulations 2014	Scheduled for action in 2016/17
6	Work with key stakeholders to ensure that short targeted training for site staff on radon prevention are developed and delivered	Course pilot and rollout scheduled for 2016.
7	Work with universities to include radon awareness in relevant undergraduate courses	Scheduled for action in later phase
8	Develop a Continuing Professional Development module on radon in cooperation with the relevant professional bodies	Scheduled for action in later phase
9	Promote targeted research on radon to support effective and efficient implementation of the NRCS	A number of research projects complete. Others are on-going.
10	Update the national assessment of indoor radon levels	First stage complete. Population weighted average to be assessed in 2017.
11	Research to assess the combined effectiveness of passive sumps and sealing the base of the building	Research has been commissioned and is underway
12	Implement a broadly based multi annual programme of local radon awareness campaigns	On-going
13	Develop and implement a national communications strategy to underpin local campaigns	Strategy developed. Pilot due in 2016. Rollout in 2017/18.
14	Implement a targeted multi-annual programme aimed at increasing awareness among different groups of "influencers"	National communications and advocacy strategy (Action 13) addresses this action.
15	Promote the continuation of the programme of radon testing and remediation of social housing	Dedicated information for local authorities published on radon.ie. Technical advice provided to support local authorities as required. Remediation Training Course attended by local authority housing staff.
16	Develop guidelines for local authorities on dealing with requests for information on radon	Complete
17	Develop a protocol for dealing with individuals with high radon measurements between: EPA, DECLG, HSE, local authorities and HSA	Communications and Advocacy strategy provides for more targeted support of householders with high radon levels.
18	Amend the advisory report which accompanies the BER certificate to include advice on radon	On target for completion in 2016/17
19	Develop a detailed strategy to examine recommendation on conveyancing	Strategy agreed. Rollout expected during 2016.

20	Amend the Housing (Standards for Rented Houses) Regulations to address radon	Review of Regulations scheduled to commence in 2016
21	Amend checklist used by local authorities for inspection of rental properties (private and social) regarding the rate of radon testing and the levels found	Scheduled for action in later phase
22	Develop a detailed paper on financial incentives to encourage action on radon	Paper developed. Implementation to be agreed and developed during 2016/17.
23	Develop framework for training in radon remediation	Complete
24	Update "Radon in existing buildings – corrective options" published by DECLG	May be addressed through Actions 2 and 23. Scheduled to be addressed in later phase.
25	Develop criteria which remediation contractors must meet in order to be included on a Government list or website	On target for completion in 2016
26	Develop validation or registration scheme for radon measurement services in Ireland	On target for completion in 2016
27	Review existing legal requirements concerning radon in workplaces together with any new requirements arising from BSS and recommend changes	Commenced
28	Co-ordinated programme to enforce regulations relating to radon in workplaces to be put in place	Commenced
29	Enhance cooperation on radon with other state agencies	Specific opportunities to be identified for action in later phase
30	Develop guidance on the need for retesting of previously remediated buildings	Commenced

Blue – Complete
Green – Action underway
Orange – Scheduled to commence in later phase

Annex 2 – Agencies represented on the Inter-departmental NRCS Co-ordination and Steering Groups

NRCS Co-ordination Group

Agency/ Department
Department Communications, Climate Action and Environment
Department of Housing, Planning, Community and Local Government
Environmental Protection Agency
Department of Education and Skills
Department of Health
Department of Jobs, Enterprise and Innovation
City and County Managers Association
Geological Survey of Ireland
Health and Safety Authority
Health Services Executive
Sustainable Energy Authority of Ireland

NRCS Steering Group on radon preventive measures
Objective: To progress priority actions related to improving radon prevention in new buildings

Agency/ Department
Environmental Protection Agency
National Standards Authority of Ireland
Radon Industry Association
Department of the Environment, Community and Local Government
Construction Industry Federation
City and County Managers Association
Health Services Executive

NRCS Steering Group on radon remediation
Objective: To progress priority actions related to promoting confidence in radon remediation services.

Agency/ Department
Department of Housing, Planning, Community and Local Government
Environmental Protection Agency
City and County Managers Association
Radon Industry Association

Ex-FAS

NRCS Steering Group on awareness raising
Objectives: To progress priority actions related to raising awareness and encouraging individual action on radon.

Agency/ Department
Department of Communications, Climate Action and Environment
Department of Health
Health Services Executive
Environmental Protection Agency

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A Survey on the Cosmic Radiation Exposure of Aircraft Crew in Europe between 2009 and 2015

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Introduction

In EAN Newsletter 36 (February 2015 [1]), the results of a survey on the regulatory approach to radiological protection of aircraft crew against cosmic radiation in Europe were published. The survey found that the regulatory requirements of Euratom Directive 1996/29 (article 42) [2] were broadly implemented. Aircraft crew whose exposure is likely to exceed 1 mSv/y are regarded as occupationally exposed workers and specific requirements for the airline company apply, such as:

- providing information about cosmic radiation exposure to the affected aircraft crew;
- making provision for assessing exposures;
- managing crew exposures through flight schedules; and
- the restriction of exposure of aircraft crew after declaration of pregnancy.

However, some differences have been noted:

- 1 mSv/y is generally the "action level" (*i.e.* when the requirements start to apply) but some countries use 6 mSv/y.
- 6 mSv/y is viewed by some countries as a "dose constraint" (that is not to be exceeded).

Analysis of the collated national regulations found different procedures used for the management of dosimetric data. For example, dose information may not always be individualised; hence only the collective exposure of aircraft crew can be presented in certain countries. Variation in the retention period for dose records was also noted, ranging from 30 to 50 years, or "indefinitely".

The survey also provided an opportunity to gather some figures related to aircraft crew cosmic radiation exposure. The mean annual effective dose and the maximum annual effective dose (as well as the number of exposed individuals) for the year 2009 were collated and published in EAN Newsletter 36. This data is also referenced in the International Commission on Radiological Protection (ICRP) publication *Radiological Protection of Aircraft Crew against Cosmic Radiation Exposure* [3]. In this document, the EAN dose information was used to assess the exposure situation of aircraft crew in a broad sense and helped in the drafting of the associated ICRP recommendations.

The objectives of this article are to provide an update of the 2009 data for the 2010-2014 period, and to identify the different factors that may influence aircraft crew exposure.

Methodology

From June to August 2016, contact was made with the responders of the 2009 survey. The objective was to collect

- the yearly number of aircraft crew in the country;
- the average dose of the aircraft crew population (mean annual effective dose);
- and the dose of the most exposed aircraft crew (maximum annual effective dose).

Data was successfully obtained from 9 countries and is presented in Table 1 below.

Two remarks:

- The period under review was initially 2010-2015. At the time of the survey, data for 2015 were only available for Finland, Germany and Lithuania. Hence, data for 2015 have not been taken into account in the analyses.
- Ireland presents the distribution of exposure of aircraft crew using [1-2], [2-4] and [4-6] mSv bands, and not individual data. For example, in Table 1, the maximal dose for Ireland is [4-6] mSv. The average dose has been calculated by dividing the collective exposure by the number of exposed individuals. The data from Ireland has not been taken into account in the analyses.

Country		2009	2010	2011	2012	2013	2014
Belgium	Average dose (mSv)	1.27	1.27	1.43	1.37	1.37	1.39
	Maximum dose (mSv)	4.77	4.55	4.70	4.59	4.36	5.43
	Number of workers	2 912	3 218	3 408	3 311	3 291	3 438
Czech Republic	Average dose (mSv)	1.09	1.63	1.62	1.48	1.34	1.42
	Maximum dose (mSv)	3.85	3.34	3.73	4.07	3.71	5.25
	Number of workers	2 158	2044	1863	1943	2190	2208
Finland	Average dose (mSv)	2.39	2.42	2.5	2.33	2.33	2.39
	Maximum dose (mSv)	5.6	5.30	5.30	5.00	5.10	5.10
	Number of workers	3 655	3 428	3 631	3 601	3 780	3 654
France	Average dose (mSv)	2.2	2.1	2.00	1.80	1.90	1.80
	Maximum dose (mSv)	5.5	4.9	4.70	4.40	4.50	4.20
	Number of workers	19 830	19 532	21 195	20 823	18 979	18 110
Germany	Average dose (mSv)	2.3	2.3	2.1	2	1.9	1.9
	Maximum dose (mSv)	7	7.1	6.5	6.4	6.2	5.7
	Number of workers	36 596	37 075	39 424	40 131	39 417	39 949
Greece	Average dose (mSv)	N/A	N/A	0.88	1.18	1.07	0.97
	Maximum dose (mSv)	N/A	N/A	2.13	3.16	3.16	2.49
	Number of workers	N/A	N/A	1567	1395	1224	1552
Ireland	Average dose (mSv)	N/A	≃ 2.6	≃ 2.6	≃ 2.5	≃ 2.6	≃ 2.6
	Maximum dose (mSv)	N/A	4–6	4–6	4–6	4–6	4–6
	Number of workers	9726	11 077	11 363	12 036	12 244	13 003
Lithuania	Average dose (mSv)	N/A	0.57	1.01	0.88	0.81	0.97
	Maximum dose (mSv)	N/A	2.5	2.66	2.83	2.64	3.29
	Number of workers	213	97	277	395	509	308
Slovenia	Average dose (mSv)	1.16	1.00	1.06	0.99	1.17	1.23
	Maximum dose (mSv)	1.74	1.50	1.33	1.47	1.64	2.68
	Number of workers	322	148	141	230	200	213

Table 1. – Average and maximum exposures of aircraft crew and number of exposed individuals in 9 European countries

Figure 1 and Figure 2 present, respectively, the change in the average dose and maximum individual dose over the period of investigation.

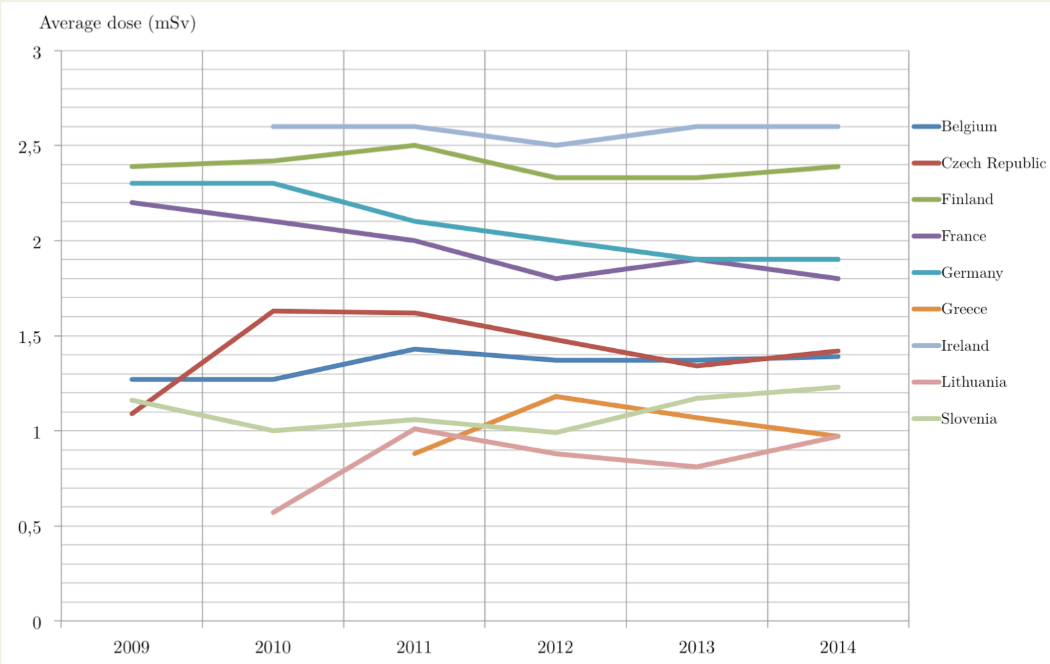

Figure 1. – Evolution of the average dose (in mSv/12 rolling months) of aircraft crew exposed to cosmic radiation for the 2009-2014 period.

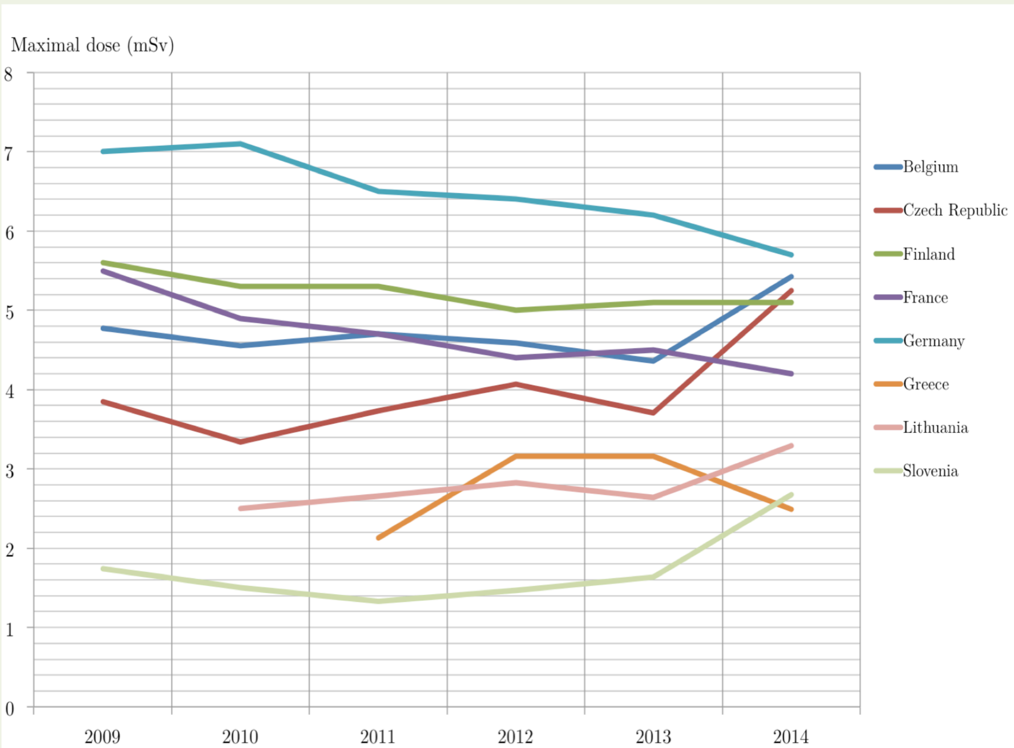

Figure 2. – Evolution of the maximum individual dose (in mSv/12 rolling months) of aircraft crew exposed to cosmic radiation for the 2009-2014 period.

Analysis of the level of exposure

Figures 1 and 2 show there are notable differences between countries in terms of average and maximum individual doses. Two groups can be separated:

- Group 1: Finland, France, Germany; where the average exposure of aircraft crew is in the order of 2 mSv/y (between 1.8 and 2.6 mSv) and the maximum individual dose is above 4 mSv/y.
- Group 2: Belgium, Greece, Slovenia and Lithuania; where the average exposure is in the order of 1 mSv/y (between 0.57 and 1.43 mSv) and the maximal individual dose is hardly above 3 mSv/y (except for Belgium where the maximum individual dose is comparable to group 1 and above 4 mSv/y).

Why do different levels of exposure arise?

Cosmic radiation exposure is not measured but estimated by an algorithm embedded in dedicated software using flight time and cosmic radiation dose rate (like SIEVERT http://sievert-system.org or CARI-6 systems). In-flight measurement campaigns show good agreement between estimated exposure and measured exposure [4].

Software generally models the atmosphere as thousands of cubes. For each cube, a pre-calculated value of the dose rate (µSv/h) is assigned, according to the altitude, latitude and solar activity. The software manager can modify the dose rates in case of change in the conditions (*e.g.* evolution of the solar activity detected by satellites or ground monitors). In-flight measurements campaigns are regularly performed to compare the calculated data with actual exposure.

The software calculates the time spent by the plane in each cube and then estimates the flight dose. The flight dose is the sum of the doses received in each cube:

$$\text{Flight dose} = \sum_i \textit{flight time}(i) \times \textit{dose rate}(i);$$

where i is associated to the ith cube of atmosphere.

Maximum flight time per year of aircraft crew is regulated in Europe and cannot exceed 1,000 hours (European regulation 83/2014). Furthermore, it is conceivable to assume that the average annual flight times of European aircraft crew are not significantly different between countries.

Hence, the different levels of exposure identified in Figures 1 and 2 probably arise from differences in the dose rates encountered during flight. The cosmic radiation dose rate varies with altitude (the higher the altitude, the higher the dose rate), latitude (the higher the latitude – toward the Poles – the higher the dose rate) and solar activity [1]. Assuming that the solar activity has the same impact on the dose rate for every country, we can investigate if there are differences in term of altitude and latitude, that is to say in term of *destinations*, between the countries.

Comparing flight destinations

Table 2 presents, for each country, the number of foreign destinations reachable by direct flight and also the number of non-European destinations and/or destinations located above the 60° parallel, reachable by direct flight. These destinations have the highest potential of increasing the exposure of the aircraft crew because of the following:

- distant destinations require a longer flight time at a higher altitude (compared to short-haul flights within Europe).
- distant destinations possibly require more flight time spent at higher latitude (many long-haul routes go across the Poles as it is often a shorter route, with reduced head wind).
- destinations located above the 60° parallel necessitate flight at higher latitude (cosmic radiation is three to five more intense in polar regions than near the equator). Reference here is to 60° parallel North, given that there is no air traffic below 60° parallel South (or only to some scientific base camps).

To obtain data for Table 2, the flight search engine "skyscanner.com" was utilised. A search was carried out for all flights departing from the countries in January 2016 and only direct flights were considered.

Empirically, it seems that countries from Group 1 (Finland, France, Germany and Ireland) have the highest overall number of destinations, and the highest number of 'penalising' destinations (non-European and or > 60° parallel destinations) on their reach. To be more specific, Figure 3 plots the average and maximum doses of aircraft crew (year 2014) against the number of penalising destinations for each country.

Country	Number of foreign destinations reachable with direct flight	Number of non-European and/or > 60° parallel destinations reachable with direct flight
Belgium	41	18
Czech Republic	27	8
Finland	32	32 [A]
France	82	57
Germany	76	45
Greece	24	8
Ireland	24	5
Lithuania	17	6
Slovenia	14	2

A. Helsinki international airport is situated just above the 60° parallel, hence all destinations from Finland are considered as penalizing destinations.

Table 2. – Number of foreign destinations and number of non-European and/or high latitude destinations reachable with direct flight.

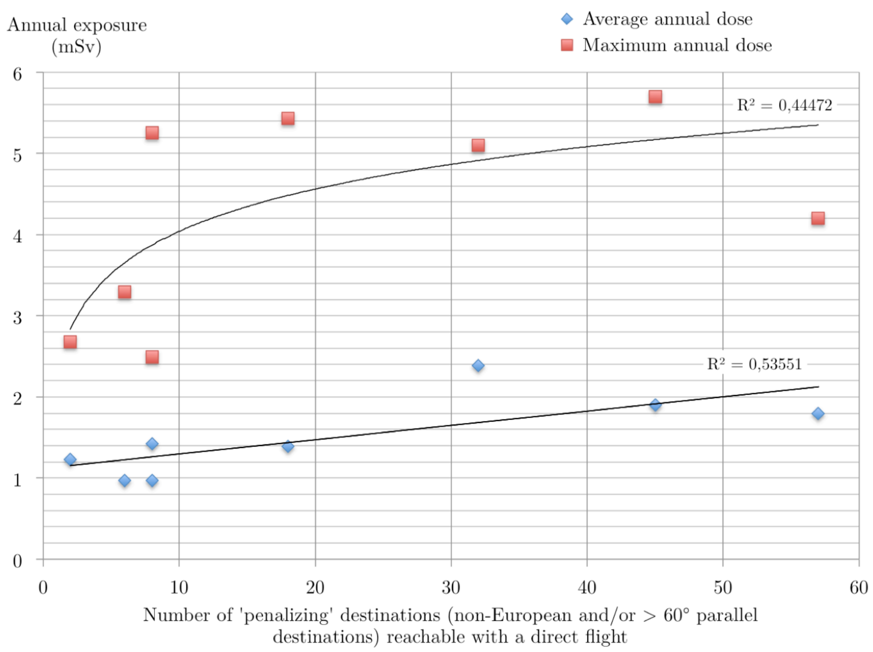

Figure 3. – Plotting average annual dose and maximum annual dose of aircraft crew against the number of penalising destinations for 2014.

We can support the empirical hypothesis by using regression analysis – a regression curve has the property of estimating the statistical significance of correlation between data variables using the least squares method (*i.e.* minimising the distance between observed distribution of data and the fitted data provided by a model [5]).

- There is a positive correlation between the number of penalising destinations and the average dose of the aircraft crew population. A linear model best fits with the data and has a correlation ratio of R^2 = 0.54, which is almost significant[1].
- There is a positive correlation between the number of penalising destinations and the potential of having an elevated maximum individual dose. A logarithmic model best fits with the data and has a correlation ratio of R^2 = 0.44 (linear model have R^2 = 0.25).

[1] For a linear regression, the critical correlation ratio is

$$R(\alpha) = t(\alpha) / \sqrt{(n - 2 + t(\alpha)^2)}$$

where t(α) is obtained given the risk α in a lognormal distribution table and *n* is the number of observed couple. In this case, with an error risk of α = 5%: $R_n(\alpha) = 1{,}96 / \sqrt{(8 - 2 + 3{,}94)} = 0{,}62$.

The average dose and maximum dose for each country studied was also plotted against the total number of destinations available. The correlations were found to be less obvious and the regression calculation showed less significance (R^2 = 0.29 for average exposure and R^2 = 0.41 for maximum exposure).

In summary, it seems there is positive correlation between the exposures of the aircraft crew of a given country and the number of distant and/or high latitude destinations reachable by direct flight from the country.

Analysis of the variation in exposure

The influence of solar activity

The variation in exposure of aircraft crew over the years is generally explained by changes in solar activity. The Sun's magnetic field reverses its direction every 11 years (last flip was January 2014, [6]). During the time period around a reversal, the field is at a solar minimum. At the opposite ends of the spectrum are solar maximums. During maximums, the sun's activity is stronger; more Sun spots are observed and solar flares more frequent. During solar maximums, the galactic cosmic radiation exposure – which accounts for most of the total exposure to cosmic radiation – tends to decrease because the charged galactic cosmic radiation particles are more repelled by the growing Sun magnetic field. They have less potential to hit the Earth when compared to low solar activity situations. Globally, when solar activity increases (like the 2009 to 2014 period), the global cosmic radiation exposure tends to decrease (the exception to this is the case of punctual solar storm).

What are the variations in exposures of aircraft crew for the 2009-2014 period?

The change in maximum exposure has not been considered here because it is related to only one individual and is therefore statistically a weak indicator of any trend.

The variation of average exposures as shown in Figure 2 can be determined by adjusting the values of exposure E with time t, considering a linear relationship:

$$E(t) = a.t + b,$$

a and b are numbers obtained by regression. Observing the sign of factor a, when $a > 0$ the exposure is globally increasing, when $a < 0$, the exposure is globally decreasing and exposure is stable when $a \simeq 0$. When changes in exposure follow a varying up and down pattern, a linear regression does not fit ($R^2 < 0.1$).

The observed trends in exposure variation are summarised in Table 3 below. The average exposures of Finnish, French and German aircraft crew (Group 1) have decreased during the 2009-2014 period. This may be explained by the increase of solar activity during the same time. Furthermore, the influence of solar activity is more important near the Poles than near the equator and Finnish, French and German airlines use this route most often (see Table 2).

By comparison the average exposures of aircraft crew of the other countries has either increased (Lithuania) or followed an up and down pattern (Czech Republic, Greece and Slovenia).

We can conclude that the variation in exposure of aircraft crew cannot be solely explained by changes in solar activity and the associated modulation of cosmic radiation dose rate. The observed variations may also be explained by overlapping confounding factors such as:

- the introduction of different flight profiles during the period (*e.g.* new planes are able to climb and descend faster, and reach higher altitudes; this may also be linked to the opening of new routes).
- the opening of new flight destinations during the period (*e.g.* introduction of ultra-long range flight routes).
- the introduction of radiation protection programmes by some airlines, like Air France [7].
- statistical variation within the aircraft crew population: new recruits (may accrue more flight hours), seniority, lifestyle, etc.

Focus on the difference between pilot and cabin crew exposure

It is sometimes reported that exposure of pilots and cabin crew to cosmic radiation are different. But the conclusions are contradictory: on one hand, cabin crew are said to have higher exposures because they fly more than pilots [8]. On the other hand, the exposure of pilots is supposed to be higher because the radiation shielding is weaker in the cockpit [9].

The exposure of pilots and the cabin crew have been separated in the data sent by Lithuania, Finland and Greece (Table 4). This gives an opportunity to see if there is a difference in the level of exposure and whether this has varied significantly over the period under analysis.

In Lithuania, the exposure of cabin crew is slightly lower than the exposure of pilots; it represents on average 83% of the dose received by pilots (σ = 18%), ranging from 42% to 98% on the 2010-2015 period. The opposite is found in Greece and Finland, where the exposure of cabin crew represents respectively 115% (σ = 14%, ranging from 98% to 123%) and 106 % (σ = 4.5%, ranging from 203% to 115%) of the exposure of pilots.

With regards to the available data, the difference between the exposure of pilots and cabin crew are not significant.

In fact, in-board measurements show that the cosmic radiation is to a large extent uniform in the aircraft, even though minor and insignificant differences may exist due to shielding by jet fuel and water tanks [10]. As a result, the only differences between crew exposures can be related to flight time. For example, cabin crew may have the potential to fly less than pilots, because part-time jobs are available. Conversely, crews may be encouraged to work extra hours due to salary incentives.

Country	Trend in the evolution of average exposure for the 2009-2014 period
Belgium	stable
Czech Republic	*linear trend does not fit: ups and downs pattern*
Finland	decrease
France	decrease
Germany	decrease
Greece	*linear trend does not fit: ups and downs pattern*
Lithuania	increase
Slovenia	*linear trend does not fit: ups and downs pattern*

Table 3. – Trends in the evolution of average exposures of aircraft crew for the 2009-2014 period.

Country		2010	2011	2012	2013	2014	2015
Finland	Pilots average dose (mSv)	2.23	2.36	2.2	2.35	2.26	2.31
	Cabin crew average dose (mSv)	2.52	2.57	2.4	2.32	2.43	2.41
Greece	Pilots average dose (mSv)	NA	0.8	1.16	1.04	0.78	NA
	Cabin crew average dose (mSv)	NA	0.93	1.19	1.09	1.08	NA
Lithuania	Pilots average dose (mSv)	1.05	1.03	0.89	0.89	1.04	1.12
	Cabin crew average dose (mSv)	0.45	1.01	0.88	0.77	0.92	0.96

Table 4. – Pilots and cabin crew average exposure in Finland, Greece and Lithuania for the 2010-2015 period.

Conclusion

Aircraft crew exposure data from 9 European countries for the period covering 2009-2015 have been gathered in two surveys. Differences between the countries exist in terms of average and maximum exposure and also in the variation of average exposure during the period surveyed.
Differences in terms of average and maximum exposure can be explained by the type of flight destination: there is a positive correlation between the exposures of the aircraft crew of a given country and the number of distant (*i.e.* non-European) and/or high latitude destinations reachable by direct flight from this country. Distant and/or high latitude destinations have the potential of increasing the cosmic radiation exposure of aircraft crew due to elevated dose rate.

Depending on the countries, the average exposures followed different trends during the years. Exposure of aircraft crew populations in Finland, France and Germany have decreased and this thought to be linked with solar activity during the period. But average exposure in the other countries have either increased or followed up and down trends, which are more difficult to explain. It would be interesting to continue to monitor the exposure of aircraft crew and evaluate any changes observed during the next solar minimum (~2017–2021).

In any case, this analysis shows that radiation protection of aircraft crew is not a common practice within the surveyed countries and that there is scope to implement radiation protection programmes and actions. ICRP [3] notably recommends airline companies to set a dose reference level, to be chosen according to the prevailing circumstances, and to apply the principle of optimisation. This may be achieved in practice by appropriate selection of flight time and flight route for the aircraft crew. ICRP also provides specific recommendations for pregnant aircraft crew (exposure to the foetus should be less than 1 mSv), and recommends that frequent-flyers and occasional passengers are informed of the exposure situation, so they can manage their exposure accordingly. ❑

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* * *

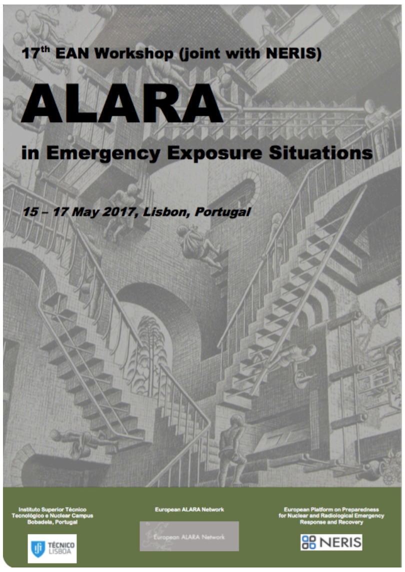
EAN Survey of Radiation Protection Practices in Dental Radiography

In order to gather a European picture of the different practices in this field, the Editorial Board and Dr. J. Holroyd (Public Health England) have drafted a short survey to gather more information about the regulations and national guidance in your country/facility regarding collimation, thyroid shielding, paralleling technique and lead aprons when it comes to intraoral, panoramic, cephalometric and dental CBCT radiography. The survey can be accessed by copying this link: https://sylvainandresz.typeform.com/to/wonS13

The survey is very short (expected completion time < 10 min) and we would urge our readers to take this short time to complete it. The results will be published and analysed in a future EAN Newsletter. Thank you in advance.

Next EAN Workshop – Preliminary program available

EAN 17th Workshop: ALARA in Emergency Exposure Situations
Organised in collaboration with NERIS
15-17 May 2017, Lisbon, Portugal



Emergency exposure situations can arise as a result of a nuclear accident, a malicious or terrorist act, or any other unexpected radiological event. It requires a quick response and sustainable countermeasures and remedial actions in order to avoid or reduce adverse short-term and long-term consequences. Radiation exposures can be received by the public, first responders, workers and volunteers engaged in the post-accident recovery.

The ICRP recommendations and European Basic Safety Standards – the bases for national regulations - re-emphasise the principle of optimisation (ALARA) as applying to emergency exposure situations. For the purpose of radiological protection, reference levels for emergency exposure situations should be set. More importantly, it is necessary to establish emergency plans based on an optimum protection strategy, resulting in more good than harm for the exposed people and the affected territories. In that perspective, lessons learnt from the Fukushima accident are of utmost importance.

The objectives of the workshop are:

- To show, in particular from experience of the Fukushima accident, the challenges posed by the optimisation of exposures in emergency and post-accident situations;
- To review the national arrangements for assessing, monitoring and mitigating the radiological consequences of an emergency, especially with regard to applying the ALARA principle to public and occupational exposures;
- To review the arrangements for managing doses to emergency workers;
- To review the arrangements for providing ALARA-based training for the different types of stakeholders who would be engaged in the emergency response and long-term recovery actions.

The preliminary program is now available on the EAN website.

In practice

All relevant information is available by following the registration link below. ❑

http://www.planetreg.com/EANworkshop17NERISworkshop3

ALARA NEWS

Workshop on reasonableness in the implementation of the ALARA principle

IRPA has been working with ICRP on the ethical values underpinning the system of radiological protection and in this context, raised some questions over the system of protection itself and how it can be sensibly presented to the public. In this context, the French Society for Radiological Protection (SFRP) organised a workshop with IRPA to further address the quest for reasonableness in the implementation of the ALARA principle. This workshop took place on 23th and 24th February 2017 in Paris and gathered more than 30 participants: representatives of national societies of radiation protection affiliated with IRPA (mainly from Europe, and also Korea and Japan) and international organizations: International Commission of Radiological Protection (ICRP), Nuclear Energy Agency (NEA), World Health Organization (WHO) etc. The European ALARA Network was also represented.

The objectives were:

- to review the implementation of ALARA and question the respective roles of decision-aiding techniques and stakeholders in the optimisation process.
- to initiate a reflection on ethical and societal values that underpin the concept of reasonableness.

Besides general presentations on the ALARA principle and culture (as developed by EAN) the implementation of ALARA has been addressed in three main contexts: ALARA in the nuclear sector, in the medical sector and in existing exposure situations (mainly radon and post-accident situations). Working groups were set up to address more deeply the different exposure situations.

The presentations are available on the SFRP website (www.sfrp.asso.fr). It is planned that the conclusions of the workshop will be further disseminated through congresses and publication. ❑

The participants of the workshop on reasonableness in the implementation of the ALARA principle, 23-24 February 2017, Conservatoire National des Arts et Métiers, Paris.

FAQ ALARA

Sensitivity to parameter values in ALARA analysis – *What if?*

By following the ALARA procedure, we should have structured the problem and identified the relevant factors and options, and determined the 'optimum' solution. However, we cannot believe that the result is the 'exact' solution as uncertainties may come from:

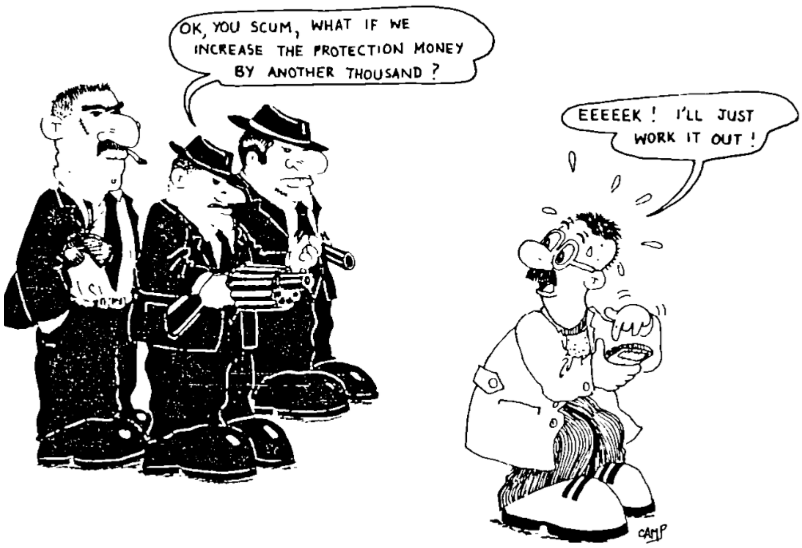
- parameter values based on data from observation, feedback, experience, measurement and assessment (*e.g.* dose rate, dose reduction factor, number of workers, cost, etc.)
- parameter values based on assumptions or value judgements reflecting impossibility or absence of direct measurement (e.g. monetary value assigned to the saving of unit collective dose, etc.)

It is important to consider how robust or 'sensitive' the results of the analysis are to the various uncertainities. This is the essence of sensitivity analysis, which is merely a term for asking the question "*What if...*?" Such an analysis tests the relative importance of the various sources of uncertainty introduced in the procedure, as well as the value judgements. The sensitivity analysis should be commensurate with the exposure situation at stake.

Having identified the main uncertainties associated with the parameters and made some estimate of their magnitude, we try to look at the influence changing parameter values has on the results of the analysis.

- The simplest method of doing this is to change the value of one parameter at a time, across its range of uncertainty previously identified, and re-evaluate the ALARA solution to the problem.
- If multiple parameters are 'uncertain' and to be changed, the analysis can be readily achieved if the analysis has been performed by means of a computer program, such as a simple spreadsheet; changing the value of a parameter allows the results to be rapidly recalculated. Graphical presentation of the information may also be helpful.
- Care is needed to ensure the sensitivity study is still *realistic* to prevent misallocation of resources.
- There are statistical techniques that are used in other areas for considering more than one parameter in an analysis at the same time. These techniques are not discussed here.

If the ALARA solution is proven to not be resilient to variations, it suggests either i) to review the sensitivity analysis to see whether the variations in the key assumptions are realistic (are they too extreme?) or ii) that the relevant options are effectively indistinguishable by the analysis. The decision-maker will then have to rely partly on *judgement* to make the final decision. ❑



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