出國報告（出國類別：開會）

赴法國參加第四屆國際輻射防護體系研討會（ICRP 2017）出國報告

服務機關：行政院原子能委員會
姓名職稱：林貞絢　薦任第九職等科長
派赴國家：法國
出國期間：106 年 10 月 8 日至 18 日
報告日期：107 年 1 月 12 日

摘要

第四屆國際輻射防護體系研討會（ICRP's 4th International Symposium on the System of Radiological Protection）於 2017 年 10 月 10 日至 12 日在法國巴黎舉行，本次會議與第二屆歐洲輻射防護研習週（The 2nd European Radiation Protection Research Week）共同舉行（ICRP-ERPW 2017），提供了世界各地輻防領域的研究者、專家、政策制定者一個分享研究成果與相互交流的平台。會議結束後，另安排赴同位於法國巴黎的經濟合作暨發展組織核能署（OECD/NEA）及法國核能安全署（ASN）參訪，了解核能署的組織架構與目前工作重點、蒐集法國對於國際放射防護委員會（ICRP）於 2007 年所提出的輻防管制體系新建議（ICRP-103 號報告）納入法國國內管制法規之推動現況與經驗，以及對於 ICRP 報告之輻射工作人員眼球水晶體劑量限值新建議之因應作為，以為未來我國推動游離輻射防護相關法案修訂與實務管制作為精進之參考。

藉本次參加會議與參訪，了解國際輻射防護最新之發展趨勢、掌握法國對於最新輻射防護建議之採納現況，並學習法國對於輻射防護相關法案之推動經驗，可為本會後續推動游離輻射防護相關法案修訂與精進管制作為之參考。本案具體建議如下：一、持續派員參與國際研討會並可就近參訪相關單位組織，吸收國際經驗。二、持續關注環境輻射防護的議題發展，以及收集其他國家對於核子事故緊急應變或其他災害的處置經驗，可有助於我國精進相關規範，與國際接軌。 三、參考法國將 ICRP-103 號報告納入法規，以及因應輻射工作人員眼球劑量修訂的操作經驗，研擬我國精進相關法規之規劃，並考量所需配套措施。

目次

壹、出國目的與行程

一、出國目的

國內已廣泛使用游離輻射於民生領域，輻射源的數量亦逐年增加，為提供更便民與安全的管制，本會近年來積極發展雲化輻射防護管制系統、簡化輻射作業的申辦流程、強化輻射災害緊急應變機制，亦持續精進相關法規。此次赴法國巴黎參加 2017 年第四屆國際輻射防護體系研討會（ICRP’s 4th International Symposium on the System of Radiological Protection），期瞭解國際最新輻防管制趨勢，以為精進我國推動相關措施之參考。

另外，會議結束後，就近參訪同位於法國巴黎的經濟合作暨發展組織核能署（OECD/NEA）與法國核能安全署（NEA），瞭解核能署目前關注的輻防議題，並學習法國對於輻防管制的經驗與作為，以為未來本會精進輻防管制法規與措施之參考。

二、出國行程

日 期	地點	工 作 內 容
106.10.8(日)- 10.9(一)	台北、巴黎	路程(台北→巴黎)
106.10.10(二)- 10.12(四)	巴黎	參加第四屆國際輻射防護體系研討會((ICRP-ERPW 2017))
106.10.13(五)	巴黎	參訪經濟合作暨發展組織核能署(OECD/NEA)
106.10.14(六)-10.15(日)	巴黎	資料整理與準備後續參訪事宜
106.10.16(一)	巴黎	參訪法國核能安全署(ASN)
106.10.17(二)-10.18(三)	巴黎、台北	路程(巴黎→台北)

貳、出席第四屆國際輻射防護體系研討會(ICRP-ERPW 2017)

第四屆國際輻射防護體系研討會為國際放射防護委員會（the International Commission on Radiological Protection；ICRP）所舉辦的國際型會議，該會議每 2 年舉辦一次，本屆會議在法國巴黎郊區的 Newport Bay Club Hotel 舉辦，與歐洲聯合研究平台(European research platforms)所舉辦的第二屆歐洲輻防研究週(The 2nd European Radiation Protection Research Week）共同辦理，並由法國輻射防護暨核能安全研究所（Institute for Radiological Protection and Nuclear Safety；IRSN）主辦。本次會議共有來自 42 個國家 500 位以上參與者共襄盛舉（如圖 1）。

圖 1、左圖：Newport Bay Club Hotel 的會議中心外觀；右圖：ICRP 會議辦理情形

歐洲聯合研究平台由 5 個研究團體共同組成，包括研究低劑量輻射影響的 MELODI（Multidisciplinary European Low Dose Initiative）、研究放射性物質對人類與生態影響的 ALLIANCE（European Radioecology Alliance）、研究輻射劑量學的 EURADOS（The European Radiation Dosimetry Group）、研究輻射醫療應用的 EURAMED（The European Alliance for Medical Radiation Protection Research），以及研究緊急應變與災後復原的 NERIS（European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery），為了促進歐洲輻射防護的發展，藉此聯合舉辦年度研討會的機會，創造研究學者可以分享研究成果、互相交流討論的機會，以期將輻射防護的研究效益與未來發展最大化。

在大會的開幕式中，ICRP 的主席 Claire Cousins 女士以「近 90 年的 ICRP」發表演說，除了回顧 1982 年以來成立至今已邁入 89 歲的 ICRP，也介紹了接下

來 5 年內（2017-2021 年）ICRP 的委員會（如圖 2）。ICRP 的委員會雖然其任務內容有隨著輻射防護的發展而改變，但許多年以來都維持 4 個委員會，一直到 2005 年第 5 個委員會成立，致力發展有關環境與物種的輻射防護。第 5 個委員會自成立迄今，於數篇報告與建議中發表了有關環境輻射防護的議題，包括 ICRP-91（A Framework for Assessing the Impact of Ionising Radiation on Non-human Species）、ICRP-103（The 2007 Recommendations of the International Commission on Radiological Protection）、ICRP-108（Environmental Protection - the Concept and Use of Reference Animals and Plants）、ICRP-114（Environmental Protection: Transfer Parameters for Reference Animals and Plants）、ICRP-124（Protection of the Environment under Different Exposure Situations）。ICRP 認為不論在計畫曝露情境中引入新射源，或考慮在既存曝露與緊急曝露情境中採取措施時，都應當適當的考量到人與環境（物種）的輻射防護，因此環境（物種）的輻射防護必須要整合到輻防體系中，因此由 2013 年起，環境的輻射防護開始整合到各個輻防領域（如圖 3）。更進一步的，自 2017 年 7 月 1 日起，ICRP 委員會再度變成 4 個，原第 5 個委員會中的環境保護的專家就併入其他委員會，以將環境(物種)的輻射防護的議題併入其他主題中討論。

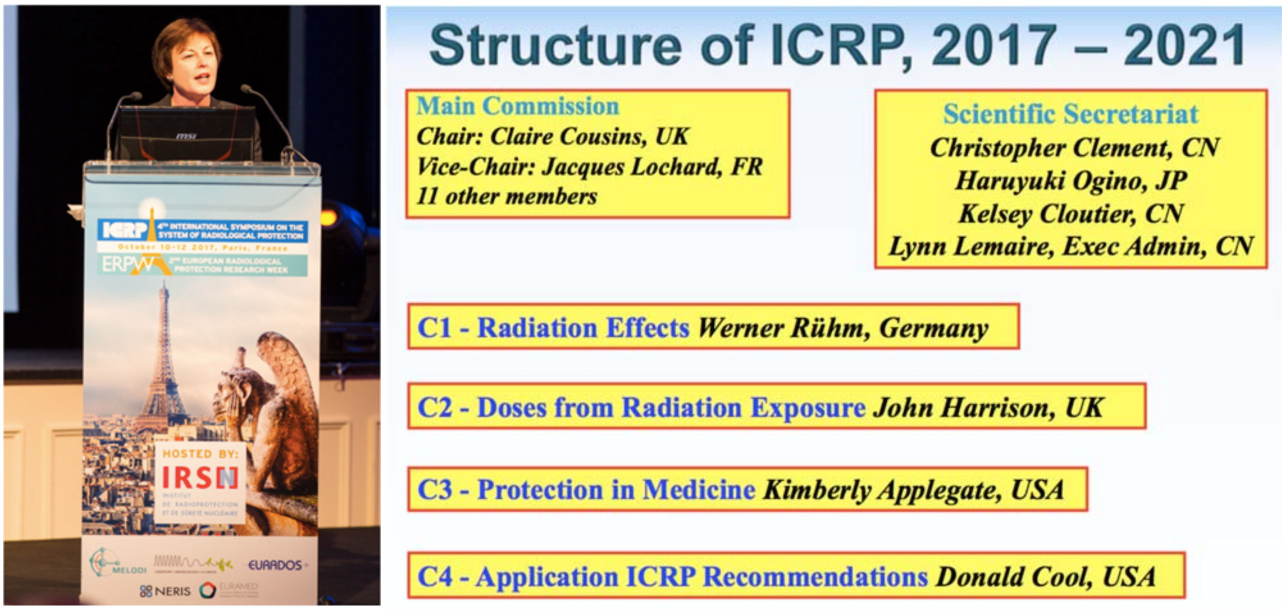


圖 2、左圖：ICRP 的主席 Claire Cousins 女士發表演說；

右圖：2017-2021 年 ICRP 的委員會的組織架構

圖 3、2013 年起，環境的輻射防護開始整合到各個輻防領域

本次會議除 ICRP 的各個委員會的報告，亦有歐洲聯合研究平台的 5 個研究團體的研究發表，以下僅就本次所聽的演講內容進行重點摘述：

一、 ICRP 委員會

ICRP 目前共有 4 個委員會，各職司不同的輻防次領域，Committee 1 負責輻射效應、Committee 2 職掌輻射劑量相關議題、Committee 3 則是醫療輻射的專家、Committee 4 提出有關輻防應用的建議，針對各委員會目前關注的議題說明如下：

（一） Committee 1（輻射效應）

Committee 1 主要關注議題為：

1. 機率效應（致癌與遺傳效應）的風險與相關的輻射作用機制。
2. 確定效應（器官或組織的功能損傷）的風險、嚴重度與相關的輻射作用機制。
3. 不同層級（如 DNA、細胞、組織、動物、人類、群體）的輻射效應。
4. 其他輻射效應的相關議題，如高背景輻射區、兒童的電腦斷層掃描、輻射敏感度與個別耐受性等。

Committee 1 目前的工作群（Task Group；TG）如下：

1. TG-64：Cancer Risk from Alpha Emitters

   TG-64 已於 2010 年出版了 ICRP 115 號報告：氡氣與其子核種造成的肺癌風險，目前持續研究其他的 Alpha Emitters 如鈽、鈾、釷、鐳可能造成的致癌風險。

2. TG-102：Detriment Calculation Methodology

輻射損傷(Radiation Detriment)是用來描述機率效應造成健康整體傷害，也就是低劑量輻射對身體健康的影響。TG-102 的目標在建立一套更佳的評估方式以計算輻射損傷，因此目前正在重新檢視 ICRP-103 報告中的對於輻射損傷的計算方法，以期精進之。

3. TG-91：Radiation Risk Inference at Low-dose and Low-dose Rate Exposure for Radiologic Protection Purpose：Use of Dose and Dose Rate Effectiveness Factors

由於低劑量與低劑量率的情況下，統計上很難預估輻射致癌的風險，因此會使用劑量與劑量率效能因子(Dose and Dose Rate Effectiveness Factors；DDREF)，將高劑量與高劑量率曝露條件（例如核爆生存者）所得的輻射致癌的統計數據用以推估低劑量與劑量率曝露條件下的輻射致癌風險。ICRP 以往使用的 DDREF 為 2，但美國國家學院(National Academies)所發表的 BEIR（Biological Effect of Ionizing Radiation）VII 報告建議使用的 DDREF 為 1.5，德國輻射防護委員會(Strahlenschutzkommission；SSK)建議使用的 DDREF 為 1，而聯合國原子輻射效應科學委員會（United Nations Scientific Committee on the Effects of Atomic Radiation；UNSCEAR）則沒有使用任何因子。因此 TG-91 認為有必要重新檢視一下現有的研究數據，包括實驗數據、流行病學數據與這些研究所使用的評估模式等，以進一步地檢討評估 DDREF。

4. 除了上述的工作群，Committee 從 2016 年起也開始針對「個別的輻射敏度」與「輻射造成的心血管疾病」2 議題研擬組成工作群。

（二） Committee 2（輻射劑量）

Committee 2 主要職掌為發展評估體內與體外曝露劑量方法，包括劑量評估模型、劑量轉換係數等，以供人類與環境的輻射防護使用。

Committee 2 內有多個工作群，例如 TG-36 針對核醫藥物的劑量轉換係數進行研究、TG-90 研究體外曝露的劑量轉換係數、TG-95 研究體內曝露的

劑量轉換係數、TG-96 發展電腦模擬計算假體與輻射遷移計算方法。另外TG-103 則發展多邊形網格式（Polygon-mesh version）的新型電腦模擬計算假體，以取代原先像素式（voxel based）的假體（如圖 4），新型假體對於微小器官或皮膚組織的邊緣能定義的更佳精確，可解決原假體在進行弱穿輻射劑量係數研究時的一些限制。

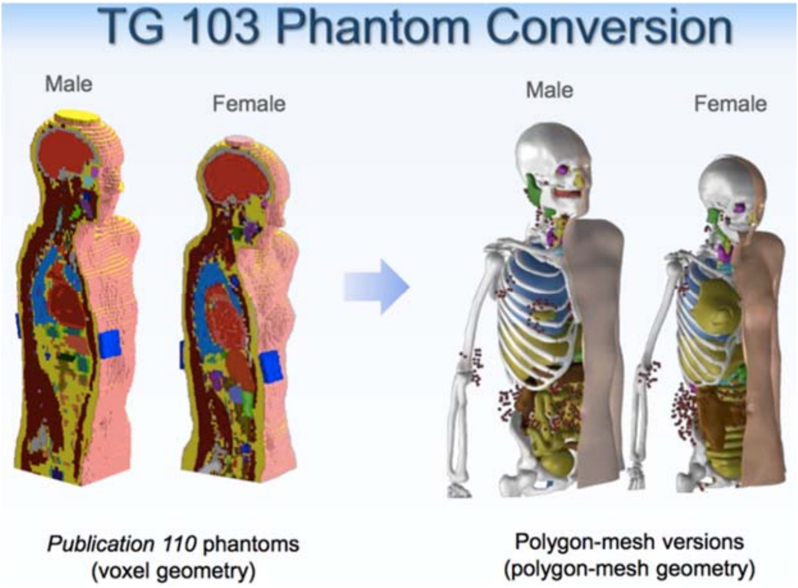


圖 4、TG-103 所發展的電腦模擬計算假體

（三） Committee 3（醫療輻防）

Committee 3 主要負責醫療診斷、治療與生物醫學研究時的人類與胎兒的輻射防護議題，現也涉及動物醫療（獸醫領域）的輻射防護議題，包括對新型醫療設備相關的輻防議題，並致力於提出更方便使用的輻防建議。

Committee 3 亦有多個工作群，發表許多醫療輻防的建議書，最近出版的建議書為 ICRP-135 號報告：醫學影像的診斷參考水平（Diagnostic Reference Levels in Medical Imaging）。此份報告說明了診斷參考水平（DRLs）的建立方法、使用原則、臨床實務的使用建議，也針對個別診療程序與兒童的診療作業提出建議。有關 DRLs 的選定與使用，此份報告也提出了以下建議：

1. 收集劑量資料以進一步選定 DRLs 值時，必須採用易於量測或易於判斷的劑量評估方式。
2. 必須使用適當的病人來進行評估（收集適當體型病人的劑量資料），不

可以使用假體。

3. 國家級或區域級的 DRLs 值都必須定期檢視更新（約 3-5 年）。
4. DRLs 值會受建立當時的醫學影像技術與實務狀況影響。
5. DRLs 值不適用於評斷個別病患的劑量。
6. 對於程序複雜的介入性診療，必須考慮要訂定 DRLs。
7. 當代表性病人們接受的劑量值的中位數大於 DRLs 值時，表示多數的病人接受的劑量值也會大於 DRLs 值。
8. 如果發現病人接受的劑量值大於地區或國家的 DRLs 值，就要進一步進行研究與採取改善措施，這就是最適化。

（四） Committee 4（輻防應用）

Committee 4 主要負責輻防原則與提出各種情境下的輻防建議，也就是整個輻防體系的架構建議。建構輻防體系時，必須在科學基礎上，納入以往的輻射作業與輻射傷害的經驗，並考量社會倫理的原則與價值（如圖 5），才能建構出可順利執行並達到防護目標的輻防體系。

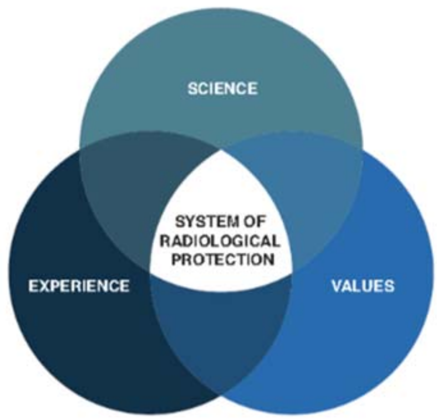


圖 5、輻防體系的建構

現行的輻防體系架構如圖 6，仍以輻防三原則：正當化（Justificaiton）、最適化（Optimization）與劑量限制（Limitation）為中心。在曝露情境上，分為既存曝露（Existing）、計畫曝露（Planned）與緊急曝露（Emergency）三情境。依照曝露類別（防護對象），則區分成職業曝露（Occupational）（輻射工作人員）、公眾曝露（Public）（一般民眾）、醫療曝露（Medical）（病人）、環境曝露（Environment）（物種）。對應不同的曝露情境與防護對象，就有不同的劑量標準可供依循，如參考基準（Reference Levels）、劑量約束（Dose Constrants）、劑量限值（Dose Limits），以及針對物種的輻防、由參考動物或植物（Reference Animals and Plants；RAP）所得之導出參考基準（Derived Consideration Reference Levels；DCRL’s）。要達到輻防原則，有些必要項目

包括事前事後的評估、責任的釐清與歸屬、過程的公開透明與架構的包容性，都必須持續的納入考量。

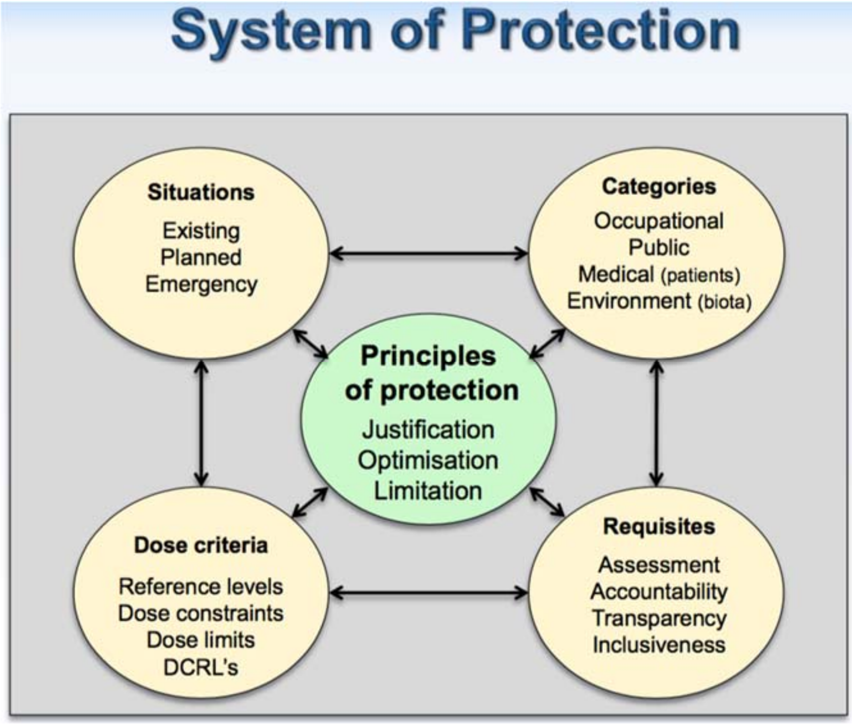


圖 6、輻防體系架構

輻防體系的建立與執行就是希望能建構輻防文化，一般來說，輻防作業會由識別曝露情境、確認這個作業是正當的開始（正當化）。正當化是輻防的首要原則，也是輻射作業的前提。接著，必須確認受曝露的對象是個人還是群體，以及是否有需要特別採行措施的利害關係人，再據以採行適當的防護措施（最適化），而個人劑量限值是輻防過程必須要達到的目標（劑量限制）。採行最適化之後，劑量分布曲線就會往左移，也就是個人接受的劑

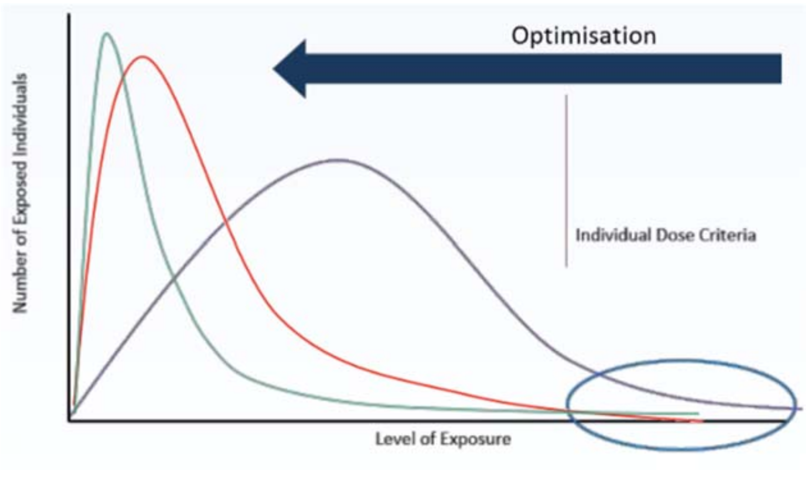


圖 7、輻防文化的建構

量會減少，接受較高曝露劑量的人數也會下降。但最適化的過程並非到此結束，而是必須不停反覆的檢視，持續精進，讓劑量分布曲線不斷往左移，群體的劑量下降，也消弭不平等的狀況，這才成功的建構輻防文化（如圖 7）。

Committee 4 所涉及的領域主要是既存曝露與緊急曝露情境，包括日本福島核子事故的經驗與教訓，以及整個輻防體系的架構與基石，並且要將環境的輻射防護整合到輻防體系中，另外針對一些關注議題，如用於人體掃描的輻射、放射性廢棄物、移動型高活度射源的輻射防護也屬該委員會負責。

在既存曝露領域，Committee 4 最近發表的建議書為 ICRP-132 號報告（Radiological Protection from Cosmic Radiation in Aviation），討論有關宇宙射線，也就是航空器工作人員的輻射防護，相關的工作群也持續關注天然放射性物質與污染區域的輻射防護。而在緊急曝露領域，預計會投注於有關核電廠以外的輻射意外事件（如恐怖攻擊）的議題討論，以期未來能更新 ICRP-96 號報告（Protecting People against Radiation Exposure in the Event of a Radiological Attack），針對輻射恐攻的輻防建議，也將多所關注寵物與家禽家畜的輻防議題，與輻射事件或事故對商業經濟的影響。

二、 歐洲聯合研究平台

2009 年，歐盟發布了一份高階專家組的報告，指出低劑量輻射議題所帶來的挑戰，也研擬了第一版的歐盟層級的研究策略（Strategic Research Agenda；SRA），並優先鼓勵多學科、跨領域的科學研究。這個策略隨後在游離輻射相關的環境議題、緊急應變與復原措施的管理上獲得推廣，因此 2010 年成立的研究低劑量輻射影響的團體 MELODI、2009 年創立的研究放射性物質對人類與生態影響的 ALLIANCE 及 2010 年成立的研究緊急應變與災後復原的 NERIS 共同組成了歐洲聯合研究平台，並獲得了歐洲原子能共同體（EURATOM）的計畫經費贊助。後來，自 1980 年代成立迄今、長期耕耘於游離輻射劑量學的研究團體 EURADOS 也加入了。最後，在 2016 年，歐洲最大的醫療輻射專家組織 EURAMED 亦加入了這個平台。

在歐洲原子能共同體的支持下，2018 年歐洲聯合研究平台也將會進行許多

研究計畫，以促進輻防領域的發展，亦依循目前歐盟最大的研究創新方案「地平線 2020（Horizon 2020）」，透過歐盟的資金挹注，讓實驗室的成果可以邁向實務走入市場，並且能有更多突破與發現。以下簡述其中幾個重要計畫：

（一） DoReMi

DoReMi（Low Dose Research towards Mutidisciplinary Integration）是一個低劑量研究的整合型計畫，計畫的目標是要促進歐洲低劑量風險研究的持續整合，以更有效的解決高階專家組所指出低劑量輻射議題所帶來的挑戰。DoReMi 計畫分成 7 個工作群，分別負責整個計畫的合作協調、核心結構、教育訓練、基礎研究的資源、劑量反應曲線研究、個人的輻射敏感度與低劑量的非致癌效應（如圖 8）。

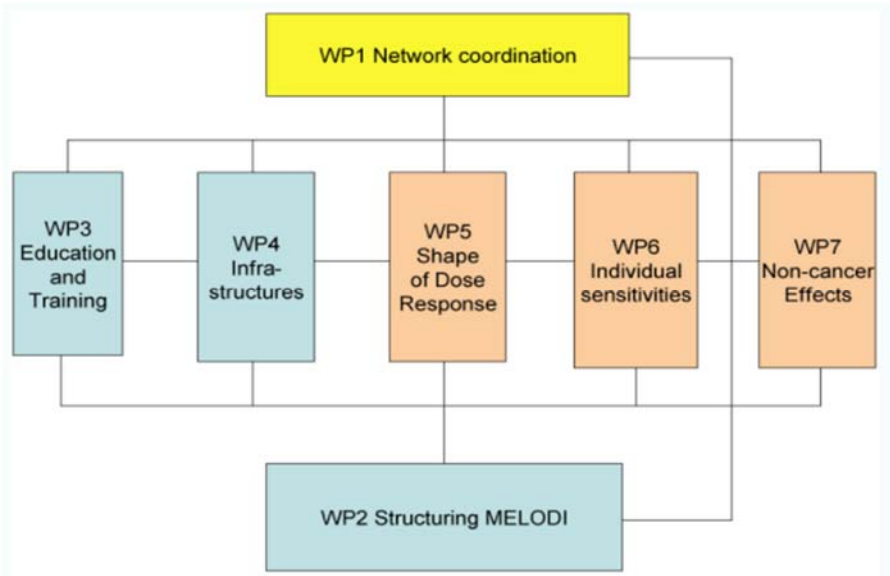


圖 8、DoReMi 計畫工作群

（二） OPERRA

OPERRA（Open Project for European Radiation Research Area）是一個開放型的計畫，鼓勵更多的歐盟會員國投身各類的輻射防護領域的研究，包括基礎研究。這個研究的最終目標是希望建立一個保護傘的結構，足以對未來的輻防研究提供更佳的管理。

（三） Concert EJP

Concert EJP（CONCERT-European Joint Programme for the Integration of

Radiation Protection Research）計畫，是致力於整合各類輻防研究的計畫，為了因應對於公眾、輻射工作人員、接受醫療輻射的病人與環境的輻防需求，此計畫將擴展到更廣泛的研究領域。

（四） MEDIRAD

MEDIRAD（Implications of Medical Low Dose Radiation Exposure）計畫致力於醫療領域的低劑量輻射照射的影響，以近一步評估醫療輻射對健康的影響。此計畫有三個目標：

1. 精進對於器官劑量的估算、優化劑量，提出建議，並對醫療輻射的流行病學研究提供適當的劑量學研究。
2. 評估與了解醫療輻射對健康的影響，其中有兩個研究重點：放射治療造成的心血管疾病的機制，與兒童接受 CT 檢查（接受低劑量輻射）對於其致癌的影響。
3. 產製以科學為基礎的政策建議，以有效的保護病人、工作人員與民眾。

三、 環境的輻射防護

環境的輻射防護議題是怎麼發展的呢？一開始這個議題只有學說、理論，接著發展出了相關的指引與工具，未來會持續發展並整合於輻防體系中（如圖 9）。

圖 9、環境輻射防護的發展

在學說理論期，ICRP 有 2 篇建議書引領了環境輻射防護的發展方向：2003

年的 ICRP-91 號報告（A Framework for Assessing the Impact of Ionising Radiation on Non-human Species）提出了游離輻射對非人類物種影響的評估架構，並建議這個架構要關注於物種本身，而不再以「人類」為出發點考量環境與物種的輻射防護，另外也提出參考動物或植物（Reference Animals and Plants；RAP）的概念。所謂參考動物或植物（RAP）如同參考人，是一個假設的生物實體，可以代表某類型的動物或植物，用來評估輻射劑量與輻射對這類型生物體的影響。到了 2007 年的 ICRP-103 號報告也說明了環境輻射防護的目的是要預防跟減少有害游離輻射對環境的影響，以維護生物多樣性、物種保存，確保自然棲息環境與生態系統的健全。

到指引工具發展的時期，ICRP 發布了 3 篇建議書：ICRP-108 號報告（Environmental Protection - the Concept and Use of Reference Animals and Plants）提出了 12 種參考動物或植物（RAP），含括了陸域、淡水與海水的生物類型（如圖 10）。也將輻防體系擴展為人類與物種輻防的 2 條平行路徑（如圖 11），這 2 條路徑的模式是類似的，但不同的是，人類的輻防所使用的劑量限值、參考基準與劑量約束用的是劑量（累積劑量），而物種的輻防所使用的導出參考基準（DCRL）則是用劑量率，並且導出參考基準（DCRL）非單一數值，而是一個範圍，一個區段，以兼顧實務執行的可行性（如圖 12）。

WILDLIFE GROUP	RAP
Large terrestrial mammals	Deer
Small terrestrial mammals	Rat
Aquatic birds	Duck
Amphibians	Frog
Freshwater pelagic fish	Trout
Marine fish	Flatfish
Terrestrial insects	Bee
Marine crustaceans	Crab
Terrestrial annelids	Earthworm
Large terrestrial plants	Pine tree
Small terrestrial plants	Wild grass
Seaweeds	Brown seaweed

圖 10、ICRP-108 號報告所提出的參考動物或植物（RAP）

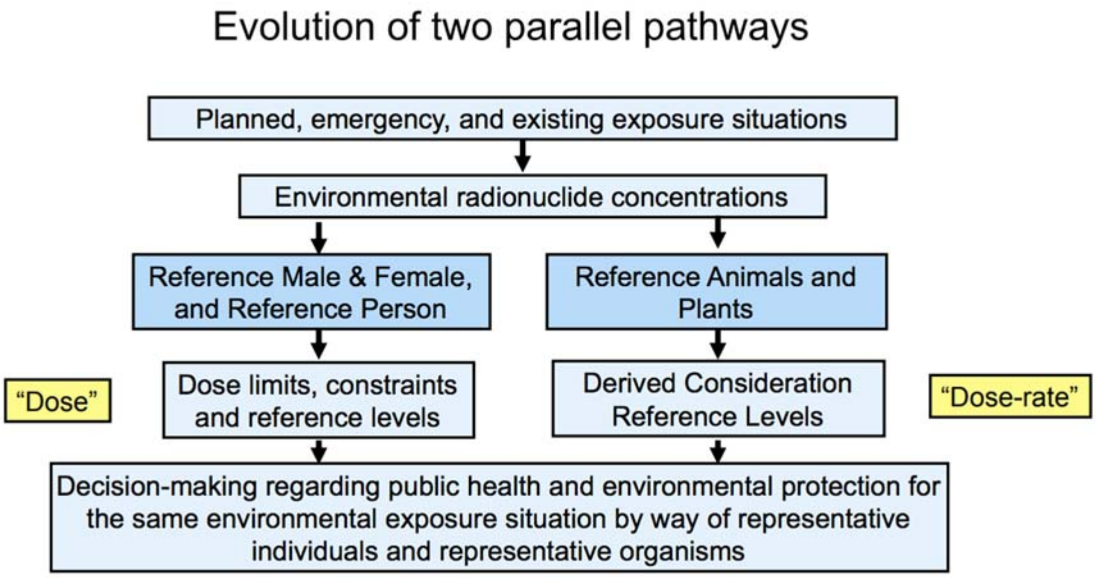


圖 11、包含人類與環境（物種）的輻防體系

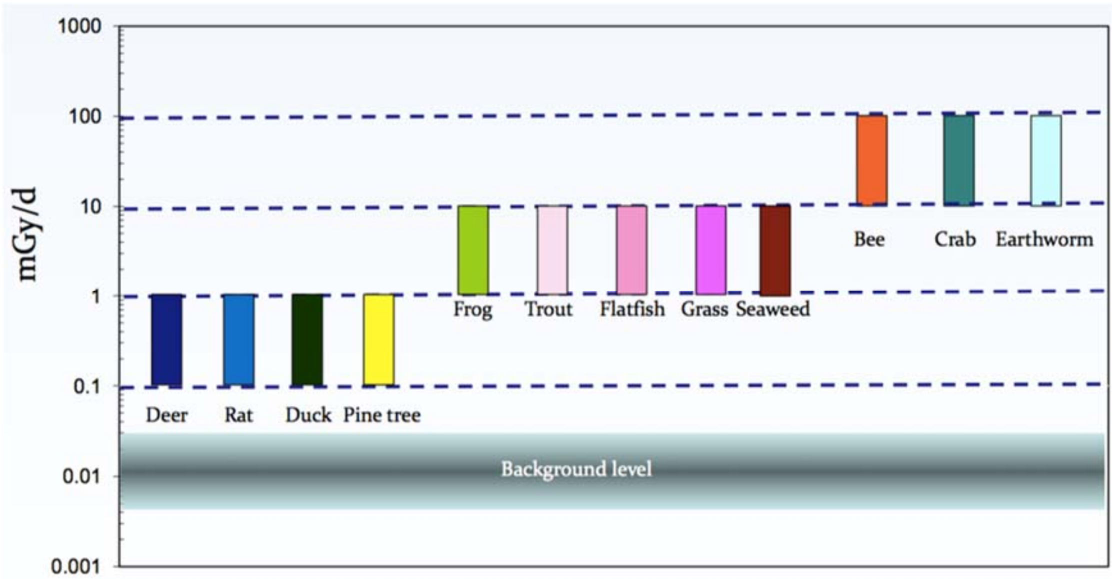


圖 12、參考動物或植物（RAP）的導出參考基準（DCRL）

到了 ICRP-114 號報告（Environmental Protection: Transfer Parameters for Reference Animals and Plants），更進一步綜整考量不同類型生物的生命週期、棲息地與放射性物質的遷移（如圖 13），依據實驗與統計數據，建立這 12 種參考動物或植物（RAP）共 39 種元素的平衡濃度比（equilibrium concentration ratios；CRs），以更加全面性的描述放射性物質的轉移。而 ICRP-124 號報告（Protection of the Environment under Different Exposure Situations）則描述了如何應用環境的輻防體系與導出參考基準（DCRL）於不同的曝露情境（如圖 14）。

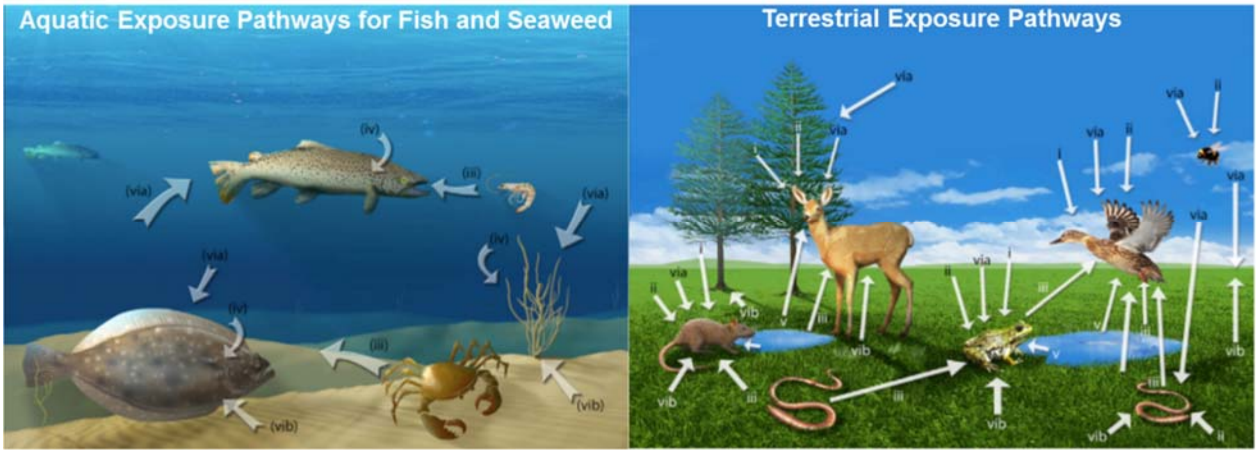


圖 13、水域（左圖）及陸域（右圖）生物接受輻射曝露的途徑

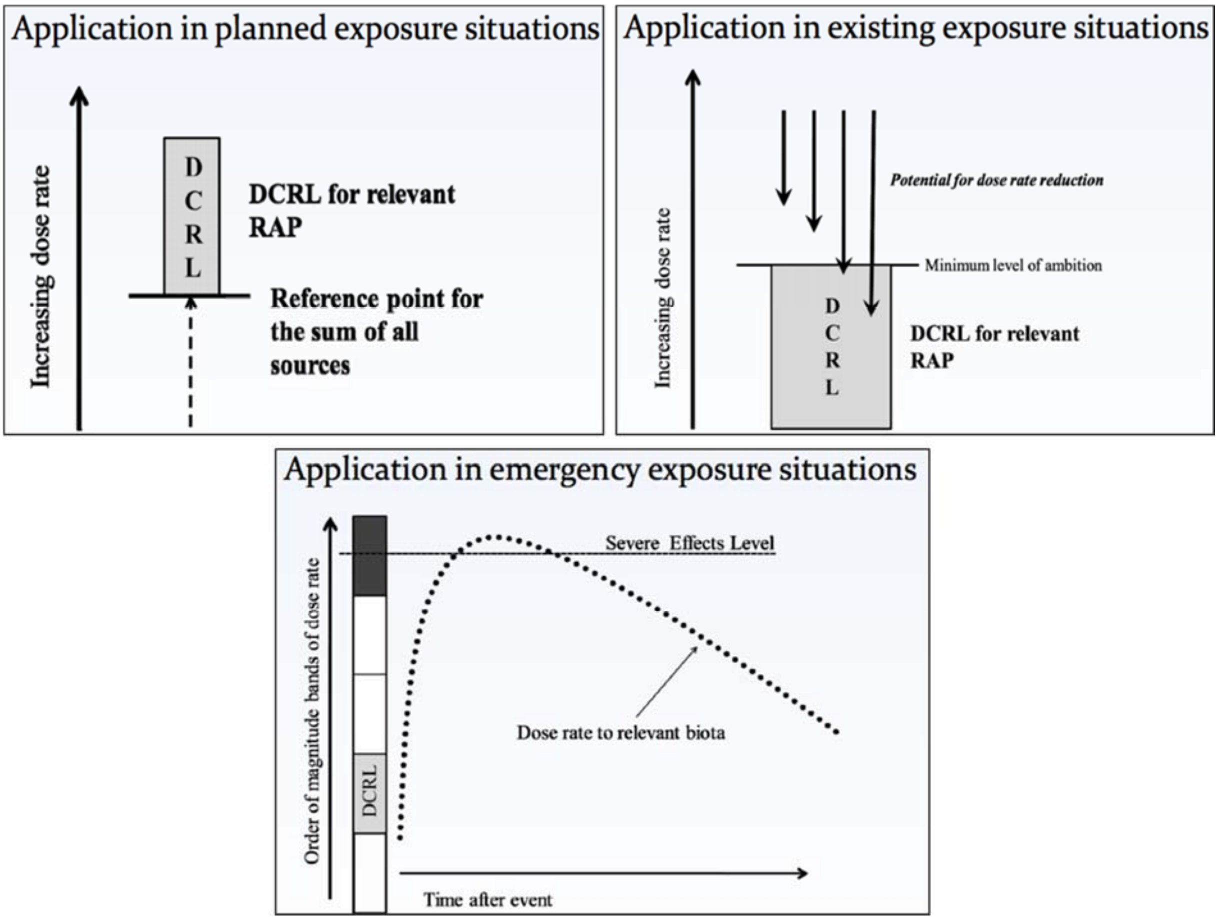


圖 14、導出參考基準（DCRL）應用於不同的曝露情境

未來，環境的輻射防護會朝向更細緻、持續更新的方向前進。其實在最近（2017 年 12 月），ICRP 就出版了 ICRP-136 號報告（Dose Coefficients for Non-human Biota Environmentally Exposed to Radiation），讓環境的輻射防護議題又更向前邁了一步。ICRP-136 號報告延續了 ICRP-108 號報告的研究，發展出了物種的劑量轉

換係數，並且產製了一個線上軟體「BiotaDC」（BiotaDC 網址為 http://biotadc.icrp.org/），透過自訂參數的方式，自行選擇要關注的物種屬於陸域或水域生物、物種的重量、形狀，與所關注核種、體內或體外曝露，制定完成參數後，軟體經過運跑便可輸出相對應的劑量轉換參數（如圖 15）。

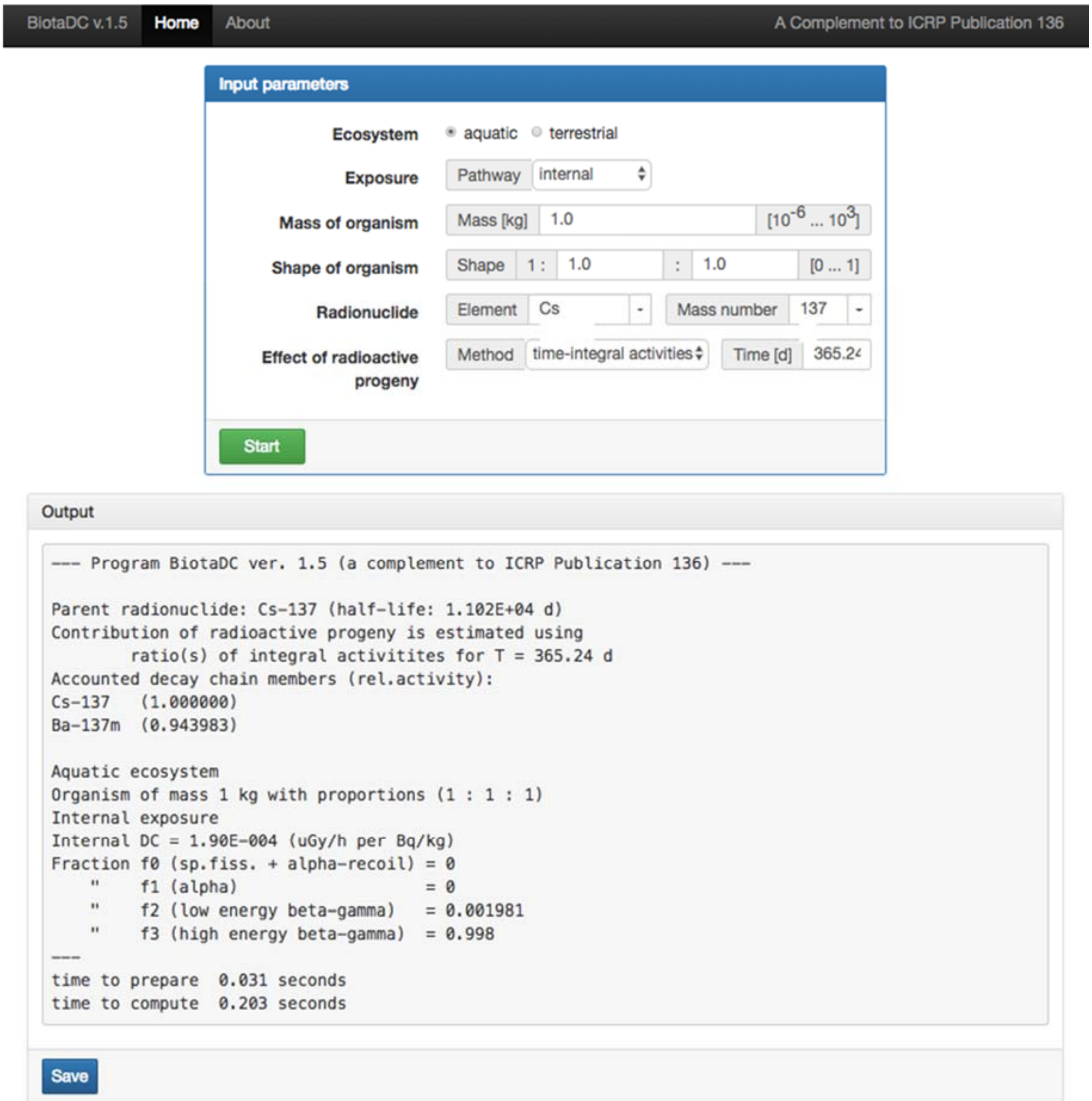


圖 15、ICRP-136 號報告所發展的線上軟體「BiotaDC」的畫面

四、 低劑量輻射引發水晶體白內障的機制研究（LDLensRad 計畫）

白內障造成失明的主要的病因之一，有多種原因都可能導致白內障，如年齡、基因（先天性白內障）、陽光、酒精、尼古丁、糖尿病或持續使用皮質類固醇等，而白內障也是游離輻射會造成的確定效應之一（屬晚期效應）。為了解低劑量輻射造成或促進白內障的完整機制，在歐盟的 Concert 計畫下，2017 年起成立了一個為期 3 年的研究計畫「LDLensRad：Towards a full mechanistic understanding of low dose radiation induced cataracts」。

LDLensRad 是一個大規模的跨域協調的合作計畫，希望能解決下述的問題：低劑量輻射如何引起白內障？劑量率的影響？遺傳背景如何影響輻射曝露後白內障的發生？這項研究還將探討眼球水晶體是否可以作為全球化的輻射敏感度指標。LDLensRad 計畫下有 5 個工作群，分別負責老鼠實驗、細胞實驗、輻射敏感度指標的探討、數據統計分析，以及研究計畫的管理與研究成果的傳播。目前研究仍在進行中，期望最終研究成果能讓我們更加了解低劑量輻射造成的白內障形成的機制。

五、 核子事故緊急應變的疏散作業（日本福島事故的教訓）

2011 年日本福島事故後，核子事故緊急應變的疏散（evacuation）作業發生了巨大的改變。福島事故時，由於原先的緊急應變機制無法發揮預期功效，因而轉以依據電廠狀態進行民眾防護行動，疏散區域也隨著事故演進不斷擴大，到了 3 月 15 日，電廠周邊半徑 20 公里內的區域都是疏散區，20-30 公里須進行掩蔽（shelter）（此區域於 10 天後改為建議可自行疏散區）。雖然電廠周邊半徑 20 公里內的居民都被疏散了，但到 3 月底，仍有居民會返家收拾東西，因此日本政府在 4 月 22 日將電廠周邊半徑 20 公里內的區域劃定為限制區（restricted area），進出需受管制。事實上，在電廠周邊半徑 20 公里外，也有部分區域被疏散，而移居的標準是該區域一年內的預期劑量（projected dose）會大於 20 毫西弗之區域。最後，有超過 10 萬民居民被迫移居或疏散。雖然，採行疏散與移居措施，確實有助於防止或減少居民接受的輻射劑量（如圖 16、圖 17），但伴隨而來的是其他

的代價。

Estimate of Averted Dose

Locality	Effective dose (Adult, mSv)	Thyroid dose (1y old, mGy)
Namie	20	60
Futaba	37	270
Okuma	45	470
Tomioka	48	750

(Data from UNSCEAR 2013 Report, Scientific Annex A)

圖 16、日本福島事故採行民眾防護措施後預估的可減免劑量（Averted Dose）

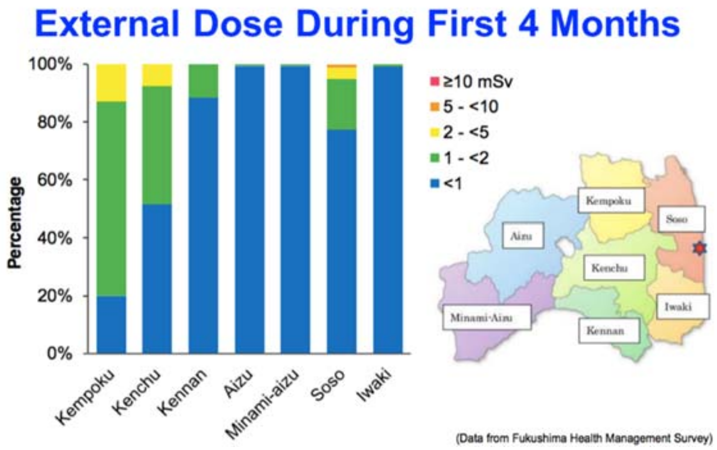


圖 17、日本福島事故發生後 4 個月內居民接受的體外曝露劑量

疏散作業所付出最嚴重的代價就是有為數不少的年長者，尤其是住在醫院或照護中心者，在疏散過程或疏散後死亡了（如圖 18）。其他被疏散或移居的民眾，其生活也遭受許多改變，包括喪失了原先的生活圈、與親人分離、被後來居住的社區隔離等，這些影響也會反應在他們的健康狀態上，包括肥胖的狀況增加，以及心理健

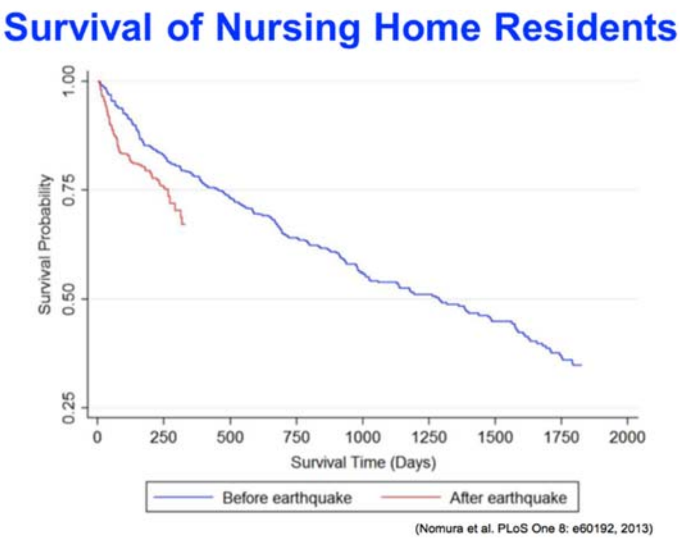


圖 18、南相馬市 5 個安養中心居民在日本福島事故發生前後的存活分析曲線

康、個人尊嚴等問題（如圖 19），因此，輻射並不是這個過程中唯一的問題。

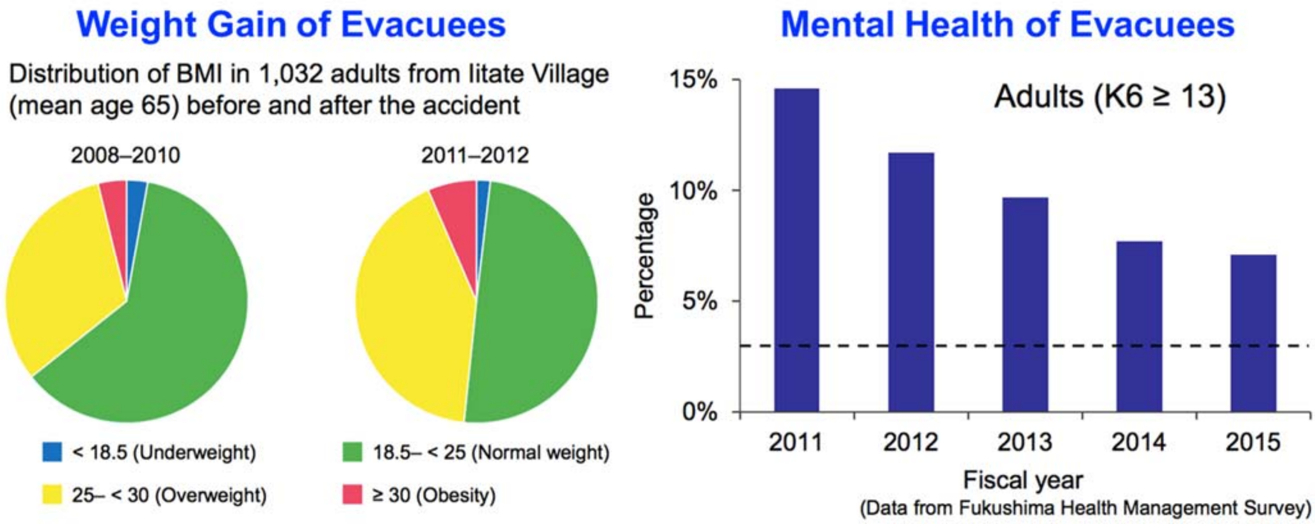


圖 19、因疏散或移居致生活方式改變之民眾，其身心健康受影響的情況

這些慘痛的經驗讓我們學到了：

（一） 依據電廠的情況進行預防性的疏散作業確實可避免或降低民眾所接受的劑量。

（二） 疏散作業必須要特別考量弱勢民眾。

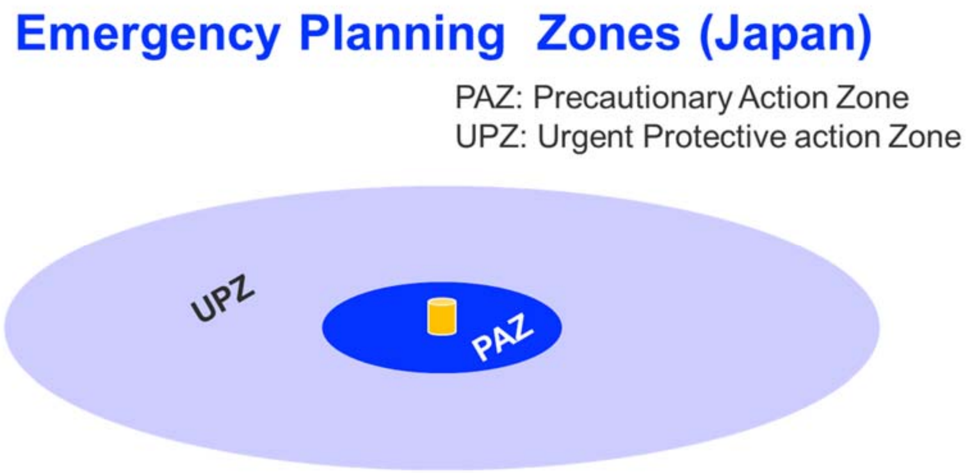
（三） 非預期的情況會帶來恐慌。

（四） 對於輻射的恐懼會產生超乎想像的反應。

（五） 長期的疏散或移居會使民眾的生活品質降低。

因此，日本政府經過深度檢討，已於 2012 年 10 月制定了核子事故的緊急應變新規範，強化了有效利用掩蔽措施，並採用可觀察（緊急應變行動基準；Emergency Action Levels；EALs）與可度量（操作干預基準；Operational Intervention Levels；OIL）的準則做為民眾防護行動的依據。另外，會特別關注需要協助的民眾，也將緊急應變計畫區（Emergency Planning Zone；EPZ）的範圍擴大。當緊急情況發生時，預防措施準備區域（Precautionary Action Zone；PAZ）的居民，就會依指示開始進行預防性疏散作業，而緊急防護措施區域（Urgent Protective Action Zone；UPZ）的居民則會採取掩蔽措施，並視狀況進行疏散作業（如圖 20）。另外在預防措施準備區域（PAZ）內的弱勢民眾，如病患、年長者、行動不便者、孕婦與嬰兒，則會有特別的安排，他們會被引導在緊急情況的早期就進入鄰近可

防輻射的避難所。



Emergency Class and Response

	Alert	Site Area Emergency	General Emergency
PAZ	●Gather Information ●Establish Means of Communication	Start evacuation/sheltering of people who require assistance	Evacuate, Take stable iodine
UPZ			Take shelter indoors

圖 20、日本的緊急應變計畫區的示意圖與各區域的防護行動

雖然疏散措施是緊急事故發生時最直接的民眾防護措施，但日本福島的經驗告訴我們，如果沒有妥善的規劃與執行，將會產生一些不好的結果。我們也必須謹記在心，疏散與移居是會影響民眾的生活與身心健康，因此在制定相關應變措施時也必須要考量這些可能的後果。

參、參訪經濟合作暨發展組織核能署（OECD/NEA）

經濟合作暨發展組織核能署（OECD/NEA）是一個跨政府的國際機構，致力於促進具有先進核能基礎設施國家之間的合作，在核能安全、技術、科學、法律上追求卓越，目前共有 33 個會員國，分布於歐洲、美洲與亞太地區，其總部設於法國巴黎。我國雖非會員國，但因參與其「核子設施除役計畫之科學與技術資訊交流計畫（Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects；CPD）」，因此與核能署簽有合約，派駐本會資深人員擔任顧問。

職藉本次赴巴黎參加會議的機會，安排赴 NEA 參訪，在本會派駐顧問林副組長的解說下，初步瞭解 NEA 的組織架構與任務。NEA 設置核能指導委員會（Sterring Committee for Nuclear Energy），為 NEA 最高決策單位，每年 4 月和 10 月召開委員會議。核能指導委員會下設有 7 個常設的技術委員會（如圖 21），負責監督轄下的專門工作組和任務組，分別為：

1. 核能管制委員會（Committee on Nuclear Regulatory Activities；CNRA）
2. 核設施安全委員會（Committee on the Safety of Nuclear Installations；CSNI）
3. 放射性廢棄物管理委員會（Radioactive Waste Management Committee；RWMC ）
4. 輻射防護與公共健康委員會（Committee on Radiological Protection and Public Health；CRPPH）
5. 核能法規委員會（Nuclear Law Committee；NLC）
6. 核能發展與核燃料循環技術與經濟研究委員會（Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle；NDC）
7. 核子科學委員會（Nuclear Science Committee；NSC）

我國參與的 CPD 計畫係屬放射性廢棄物管理委員會（RWMC）轄下的「除役及拆除物料管理工作組（Working Party on Decommissioning and Dismanting；WPDD）」之計畫，此計畫的目的在交流與分享有關除役的經驗與訊息，因此必須為除役中或即將除役的核設施才得以加入。核研所自 2004 年起，便以台灣研究用反應器（TRR）之除役計畫加入 CPD 計畫，而台電核一廠的除役計畫經過

多年的努力，也於 2014 年加入 CPD 計畫，使我國核電廠的除役作業能與國際接軌。

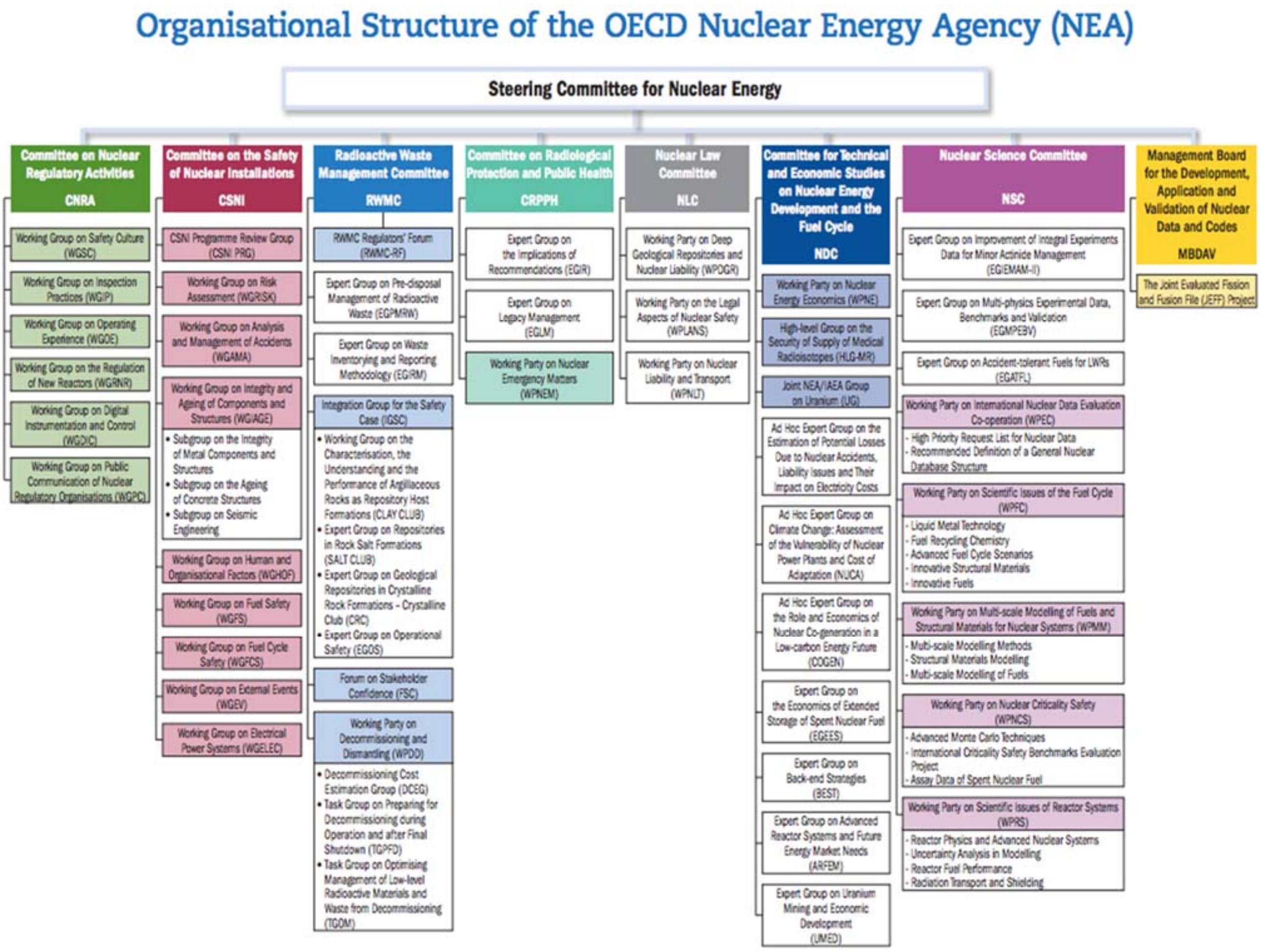


圖 21、核能署的組織架構圖

肆、參訪法國核能安全署（ASN）

法國核能安全署(The French Nuclear Safety Authority；法語：Autorité de sûreté nucléaire；ASN) 負責法國核能安全、輻射安全與核能資訊透明化管制，係依據 2006 年 6 月 13 日通過之「第 2006-686 號法案」(又稱「TSN 法案」，即涉及有關核能安全與資訊透明之法案（Act No. 2006-686 on Transparency and Security in the Nuclear Field）所設立之獨立行政機關。ANS 的前身為核能安全與輻射防護總局（the General Direction for Nuclear Safety and Radioprotection），隸屬於法國經濟金融部（the Ministry of Economy, Finances and Industry）。「第 2006-686 號法案」促使 ANS 成為現今獨立之管制機構，並賦予了 ANS 除原先的核能與輻射安全政策推動與管制任務，亦須負責有關核能資訊透明化之推動與管制作業。

本次參訪 ASN，主要與業務部門（Ionizing Radiation and Health Department）的資深顧問 Chantal BARDELAY 女士進行討論，了解 ASN 的組織架構、法國的輻防管制與立法架構，並針對法國對於 ICRP 委員會所提出之輻防新建議（包含 ICRP-103 號報告，以及輻射工作人員眼球水晶體劑量限值新建議）之推動現況與未來方向等進行深入討論，以下就 ASN 的組織架構與各項討論議題重點摘述：

一、 ASN 的組織架構

ASN 的組織架構如圖 22，由委員會（Commission）、署長（Director General）、8 個業務部門（Department）、11 個地方單位（Regional Divisions）組成，整個 ASN 有近 500 位員工，其中 80%以上都是行政職。另外，ASN 還有一個由輻射防護與核能安全專家組成的技術支援單位「輻射防護暨核能安全研究所(the Institute for Radiation Protection and Nuclear Safety；IRSN)」，IRSN 約有 1,700 位員工，均為相關領域的專家與研究員。ASN 組織中各成員的職掌與相關說明如下：

（一） 委員會：ASN 委員會共計有 5 位委員，均為全職委員，職司 ASN 的政策制定，ASN 委員會的主席為 ASN 最高領導者；5 位委員中有 3 位由總統指派（包括現任主席 Pierre-Franck CHEVET）、 1 位由參議院（即上議

院）議長指派、1 位由國民議會（即下議院）議長指派。委員的任期為 6 年，每位委員都有各自的委員任期起始與終止日期。

（二） 署長：ASN 設署長 1 人，綜整管理 ASN 的運作，現任署長為 Olivier GUPTA。

（三） 業務部門：ASN 設有 8 個業務部門，各部門的分工如下：

1. Nuclear Power Plant Department：管制與監督運轉中核電廠的安全。
2. Nuclear Pressure Equipment Department：管制監督核能設施中壓力設備（pressure equipment）的安全。
3. Transport and Sources Department：管制監督醫療院所以外其他輻射作業設施的安全，放射性物質的運送安全與保安。
4. Waste, Research Facilities and Fuel Cycle Facilities Department：管制監督核燃料循環設施、研究設施、除役的核設施、污染區與放射性廢棄物。
5. Ionizing Radiation and Health Department：管制監督醫療輻射設施，並與 IRSN 以及其他的衛生主管機關合作，關注與健康相關的議題。
6. Environment and Emergency Department：監督環境的輻射防護，處理緊急狀況。
7. International Regulation Department：負責國際事務。
8. Communication and Public Information Department：負責進行 ASN 政策的公眾溝通、核能安全與輻防知識的傳遞。

（四） 地方單位：ASN 設有 11 個地方單位，如圖 23，各自負責管制所屬行政區的核能安全與輻射安全。

（五） 輻射防護暨核能安全研究所（IRSN）：IRSN 為一個由各類核能與輻射專家組成的專業研究組織，除身負核能與輻射科學研究責任，亦提供核能安全與輻防相關的服務，並配合 ASN 所推動的政策，提供許多技術支援

與專業建議。IRSN 現任理事會主席為 Dominique LE GULUDEC，IRSN 與 ASN 互動密切，ASN 委員會的主席亦為 IRSN 的理事會成員。

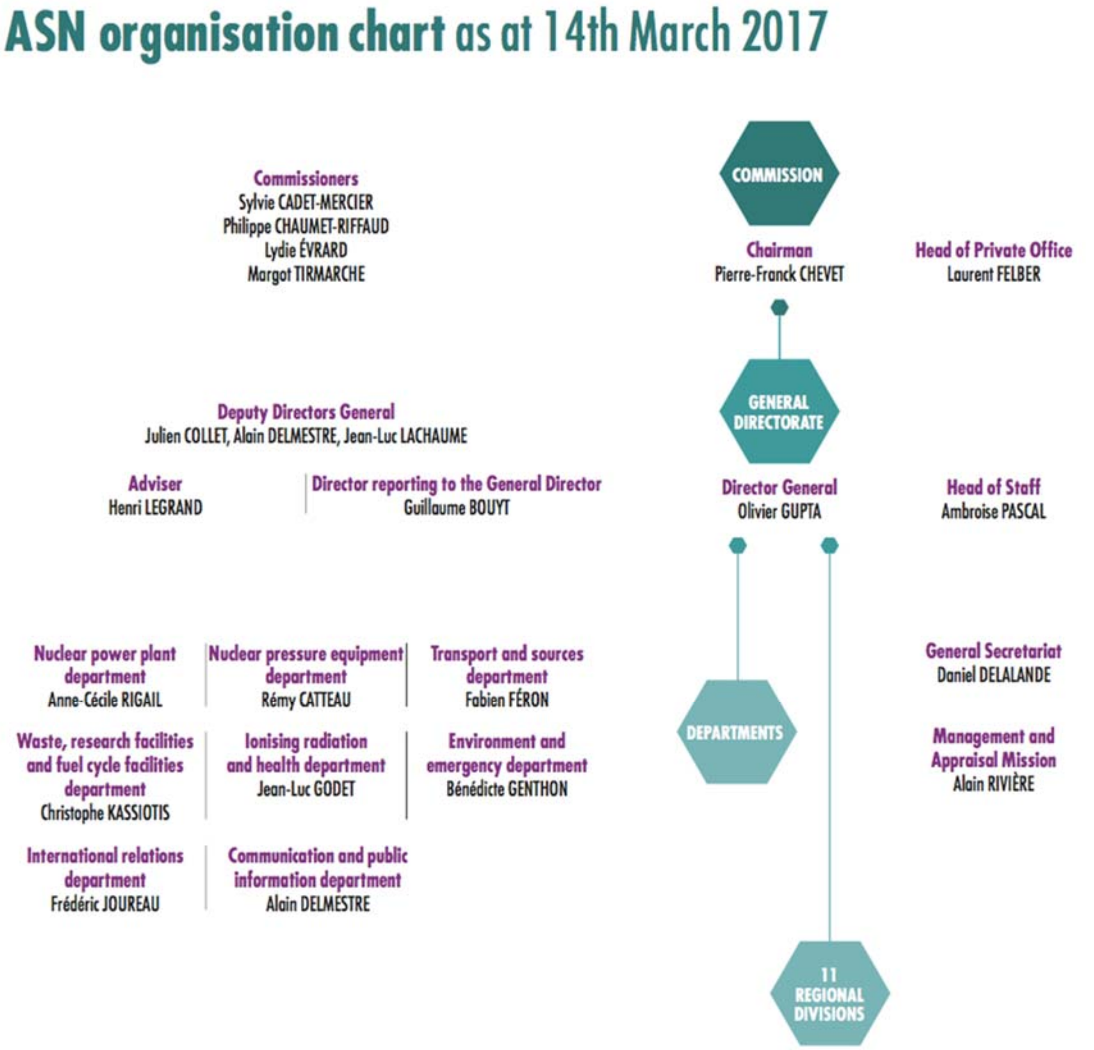


圖 22、ASN 的組織架構圖（圖片來源：ASN 2016 annual report）

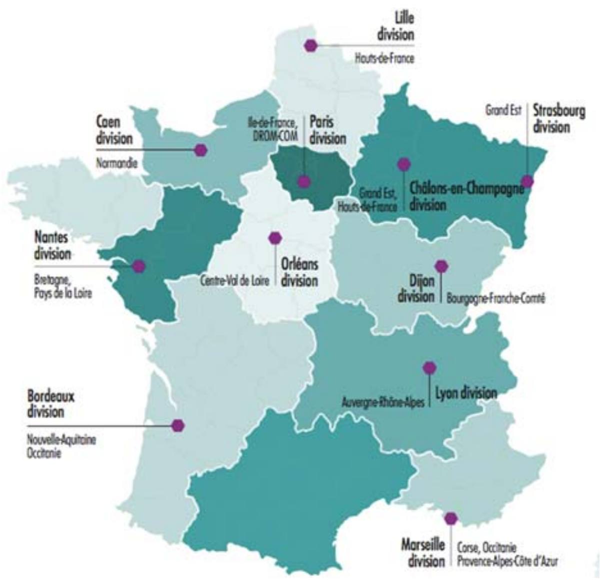


圖 23、ASN 設置的 11 個地方單位（圖片來源：ASN 2016 annual report）

二、 法國的輻防管制相關法規與立法架構

（一） 法國的輻防管制相關法規

法國的游離輻射防護管制並非如我國以「游離輻射防護法」專法進行管制，相關的規範是分列於其公眾健康法案（Public Health Code）、勞工法案（Labor Code）與環境法案（Environment Code）中，此 3 法案各有其立法主管機關，但針對游離輻射相關的規範需新增或修正時，則會由 ASN 協助訂定，此 3 法案所規範的內容簡述如圖 24。

圖 24、法國的游離輻射防護管制所涉及的法規

1. 公眾健康法案（Public Health Code）：規範一般的輻防原則與管制體系，內容涵括輻防三原則、公眾曝露、醫療曝露、緊急曝露與既存曝露各情境，如公眾的劑量限值、其他曝露情境的劑量約束。另外對於輻射源與輻射作業的管制規定，如輻射源發照與各類輻射作業申請之規定，以及建材、消費性產品與氡氣的管理。在法國，現行的管制作業，依輻射作

業的風險採分級管制，分級方式相當於 IAEA 所建議管制分級中的豁免（Exemption）、通知（Notification）與許可（License）三層級。

2. 勞工法案（Labor Code）：規範輻射工作人員的輻防事項，包括對輻射工作人員的體檢、訓練與劑量限值的規定，也規範輻射工作人員與輻防人員的資格、工作場所的管理等。

3. 環境法案（Environment Code）：屬於輻防事項的特別規範，主要規範大型核設施與放射性廢棄物所需遵循與環境的輻射安全有關的事項。

（二） 法國的輻防管制之立法架構

法國的法案位階如圖 25 所示，與我國法規體系一樣均成金字塔型，位階最高的為國際組織之建議，如 ICRP、IAEA、西歐核能管制者協會(Western European Nuclear Regulators' Association；WENRA)等組織之建議為最上層的指導原則，但無法律強制性，該等建議的數目最少。從第二層開始依序為歐盟的指引、國會的決議案、政府的法令到 ASN 的技術要求與安全指引，則都是具有法律的強制性。位階越下層的法案，其規範的內容愈詳盡，因此數量也最多。

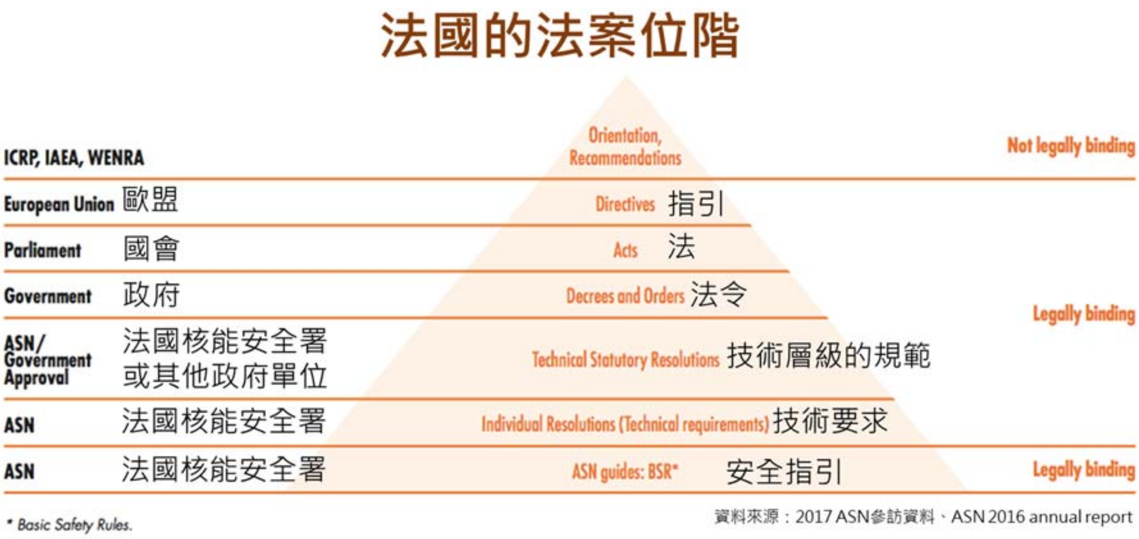


圖 25、法國的法案位階

三、 ICRP-103 號報告之推動現況與未來方向

為納入 ICRP 之輻防新建議(ICRP-103 號報告)，以及 IAEA 新的安全標準(IAEA GSR Part3)的新建議，法國已著手修訂相關的國內法規，以下針對此案推動現況，依前述法規階層分述如下，相關的時序整理如圖 26：

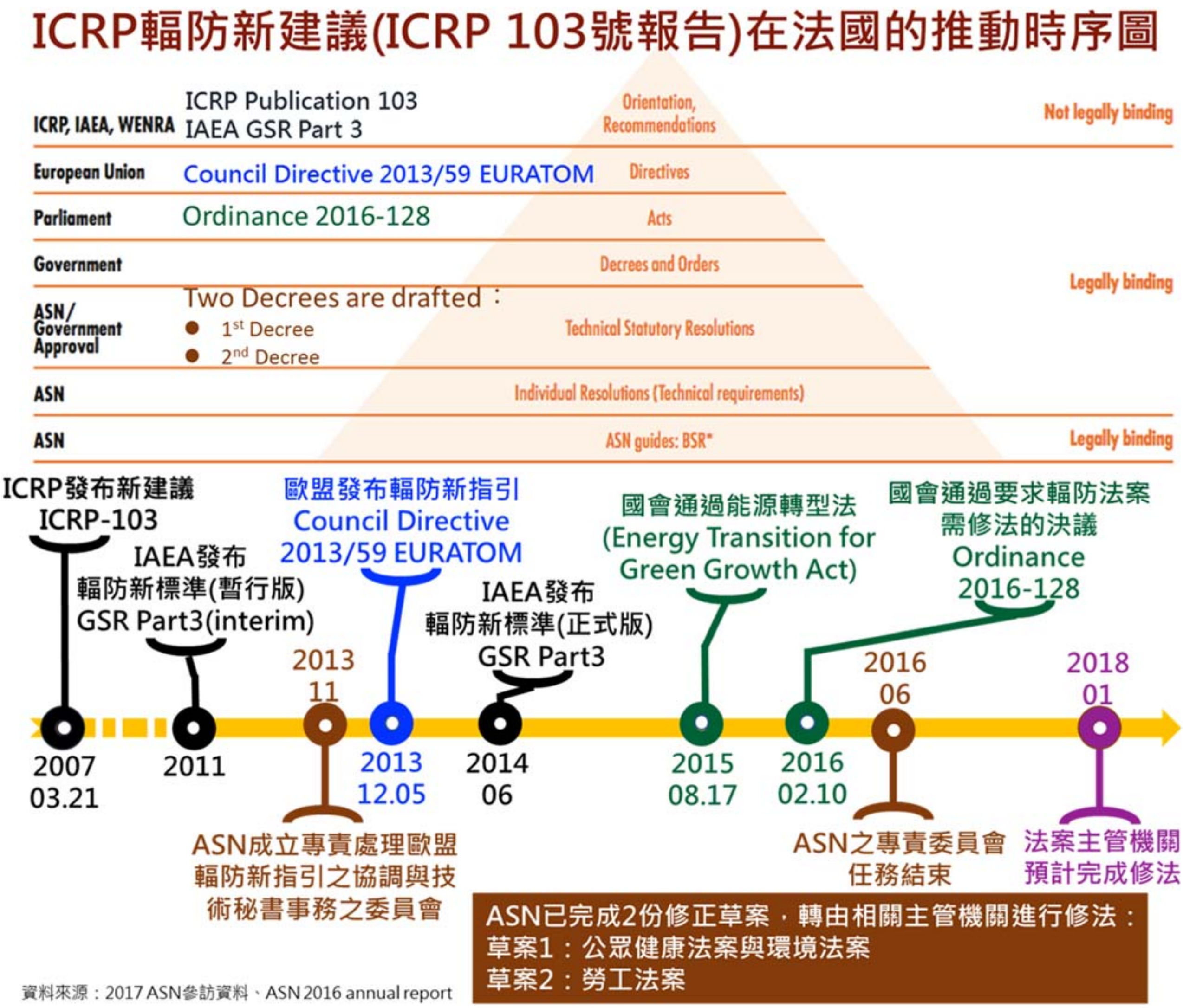


圖 26、ICRP 輻防新建議(ICRP 103 號報告)在法國的推動時序圖

(一) 歐盟層級（European Union）：歐盟於 2013 年 12 月 5 日發布輻防新指引（Council Directive 2013/59 EURATOM），採納 ICRP-103 號報告之輻防新建議與 IAEA 新標準 GSR Part 3（暫行版）。歐盟給予各會員國約 4 年的

時間檢討修正相關國內法令，也規範於新指引之第 106 條規定：歐盟各會員國需遵行該指引的規定，並據以修訂相關的國內法令。

(二) 國會層級（Parliament）：由於原子能領域的法令規定與國家的能源政策息息相關，而法國國會在 2015 年 8 月 17 日通過了一個非常重要的能源法案，第 2015-992 號法案，即「為達綠色成長之能源轉型法（Energy Transition for Green Growth Act）」。依此法案，國會也在 6 個月內的 2016 年 2 月 10 日通過了「第 2016-128 號決議（Ordinance 2016-128）」，依據此決議，法國政府須修訂公眾健康法案、勞工法案與環境法案中有關游離輻射的相關條文，並明確訂出了修正內容需要包含的項目：

1. 輻射作業（practice）的定義有更清楚的說明，需納入有關天然放射性物質（NORM）的活動。
2. 正當化（justification）與最適化（optimization）的定義有更清楚的說明，須納入參考基準（reference level）的概念。
3. 輻射風險管理分級的更新。
4. 輻射作業與所涉的工作人員、病人、大眾，以及環境之間的關聯。
5. 對於射源保安的掌控。
6. 新增有關通知潛在氡氣風險區之買者與承租者的義務。

(三) 政府層級（government）：由於 ASN 的輻防專家，亦有參與歐盟制定輻防新指引，因此約在新指引發布的同時，在法國政府的批准下，ASN 於 2013 年 11 月就成立了相關的委員會，處理有關歐盟輻防新指引納入法國國內法規相關的協調與技術秘書事務等前置作業，此作業執行至 2016 年 6 月。ASN 依據「第 2016-128 號決議」提出相關的法案修正草案、技術要求與安全指引，目前已完成 2 份修正草案，第 1 份修正草案為公眾健康法案與環境法案的修正，第 2 份修正草案則為勞工法案的修正，修正草案正轉由相關主管機關進行後續修法作業，預計今（2018）年將完成修法。修正重點如下：

1. 正當化（公眾健康法案）：調整正當化原則，將於相關法規中將「合理的活動」列表，以及新增在醫療領域中實施新的技術或新的輻射作業時，在病人有重要利害關係的情況下，可在衛生主管機關主責且 ASN 支持的情況下，允許在通過正當化之前收集病人資料的新要分布
2. 最適化（公眾健康法案）：包括最適化原則的施行，在計畫曝露的情境下（包括公眾曝露與職業曝露）導入「劑量約束（dose constraint）」的規定，在緊急曝露或既存曝露的情境下導入「參考基準（referemce level）」的規定。以下是各類參考基準：
   (1) 緊急曝露情境：有效劑量每年 100 毫西弗。
   (2) 事故後的既存曝露情境：有效劑量每年 20 毫西弗。
   (3) 建材所造成的體外曝露：每年 1 毫西弗。
   (4) 室內氡氣的濃度：每立方米 300 貝克。
3. 新的輻射風險分級管理制度（公眾健康法案）：輻射風險分級管理制度調整為 4 層級，風險由小到大依序為豁免（Exemption）、通知（Notification）、登記（Registration）與許可（License）四層級，相較現行的規定，將增加「登記」的規定，預計將現行管制作業中，部分的許可與部分的通知，改列為登記，如圖 27 所示。
4. 納入對天然放射性物質的管理（環境法案）：相關的規範將納入環保相關法規（環保區域的設施分類規定；Installation Classified Environmental Protection Grounds；ICEP Regulation），但除了天然放射性物質對工作人員的曝露外，此部分非 ASN 管制範圍。
5. 納入對氡氣的風險評估（勞工法案）：雇主在進行工作人員的風險評估時，須納入評估氡氣造成的影響。
6. 新的輻防組織（勞工法案）：對於從事一般輻射作業的單位，其輻防組織除由組織內的輻防人員，也可由其他的認可單位組成（external certified body）。但對於核能設施，其輻防組織僅可由組織內的輻防

人員擔任。這些輻防組織除需可勝任有關職業曝露的輻射防護，也必須可執行有關公眾曝露的輻射防護事宜。

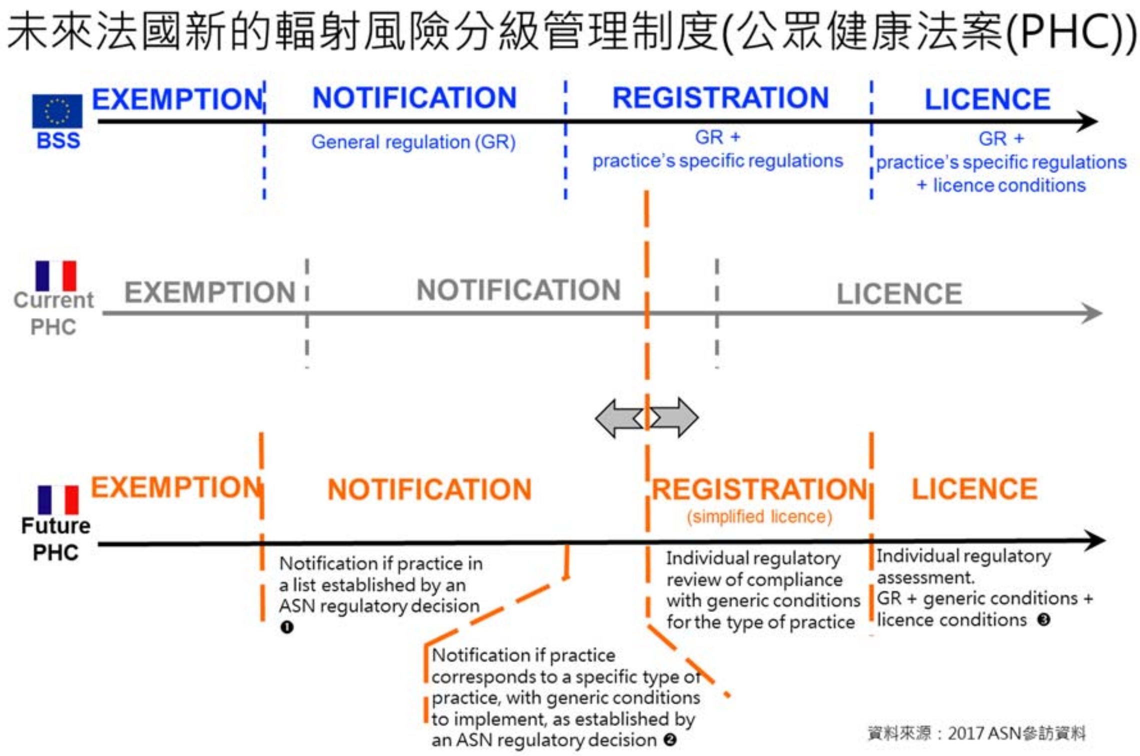


圖 27、未來法國新的輻射風險管理制度

另外，雖然 ICRP-103 號報告將原先以輻射作業與干預兩種方式進行管理的架構修改為以職業曝露、緊急曝露與既存曝露等三種曝露情境，但經本次訪談了解，法國 ASN 經過法規檢視，因其現行法案架構已含括三種曝露情境，因此法案架構將不會大幅調整，原有名詞也將繼續沿用。

四、 針對輻射工作人員眼球水晶體劑量限值新建議之因應作為

（一） 背景說明

訂定眼球水晶體劑量限值之目的是為避免眼球水晶體發生輻射曝露之確定效應，即水晶體混濁與白內障。現行的輻射工作人員眼球水晶體劑量限值「每年 150 毫西弗」，是 1990 年代 ICRP 依據過往的研究成果「單次急性曝露劑量達 0.5-2 戈雷或長期曝露劑量達 5 戈雷，會造成水晶體混濁；單次急性曝露劑量達 5 戈雷或長期曝露劑量達 8 戈雷，會造成白內障。」所訂出的眼球水晶體閾劑量 2 戈雷

（閾劑量為有 1%可能性會造成特定器官或組織效應（確定效應）的劑量值）而訂定。但 2012 年出版的 ICRP 118 號報告，已依據新的流行病學研究成果，將輻射工作人員的眼球水晶體閾劑量修訂為 0.5 戈雷，因此 ICRP 針對輻射工作人員的眼球劑量限值之建議，已由「每年 150 毫西弗」修訂為「連續 5 年 100 毫西弗，即每年平均 20 毫西弗，且單一年不得超過 50 毫西弗」。

在 2012 年 ICRP 118 號報告出版前後，歐洲有許多針對輻射工作人員眼球水晶體劑量與防護的研究，最著名的大型研究計畫有「ORAMED：Optimization of Radiation Protection of Medical Staff」與「EURALOC：European Epidemiological Etudy on Radiation-Induced Lens Opacities among Interventional Cardiologists」，都在歐盟的資助下完成，相關的研究重點摘述如下：

1. ORAMED：Optimization of Radiation Protection of Medical Staff
   (1) 執行期間由 2008 年 2 月到 2011 年 1 月，為期 3 年。
   (2) 此計畫發展出可直接量測眼球水晶體劑量之個人體外劑量計(EYE-D™，如圖 28)、建立適宜的校正方式，並於 6 個國家，每個國家 3 家醫療院所中，針對進行 10 種介入性診療作業的醫療工作人員進行個人等效劑量 Hp(3)量測。經過量測並結合工作負荷計算，結果顯示：部分介入性診療的醫療工作人員之眼球水晶體劑量有可能超過一年 20 或 50 毫西弗。

圖 28、可直接量測眼球水晶體劑量之個人體外劑量計 EYE-D™

(3) 前述Hp(3)的量測結果與利用度量Hp(7)後再校正至Hp(3)的方法進行比較，結果顯示：兩種方法所獲得的劑量值是相當的。

(4) 此計畫也針對介入性診療的輻射防護措施提出建議，包括使用懸吊式屏蔽（可減眼球水晶體接受劑量達 1.5-8 倍）、佩戴適合的鉛眼鏡（可減眼球水晶體接受劑量達 3-6 倍），以及針對介入性診療的工作人員須進行眼球水晶體劑量的監測等（針對此計畫進行的 10 種介入性診療作業，除診斷及治療性內視鏡逆行性膽胰管造影術（ERCP）造成的眼球水晶體劑量較低，無需進行例行監測，其餘作業均需進行例行輻射監測）。

2. EURALOC：European Epidemiological Study on Radiation-Induced Lens Opacities among Interventional Cardiologists

(1) 執行期間由 2014 年 12 月到 2017 年 5 月，為期 2 年半。

(2) 此計畫進行大規模的介入性診療工作人員眼球水晶體混濁病變之研究，總計有 12 個國家，393 位從事介入性診療作業的醫師與 243 位眼球水晶體未受輻射曝露的對照組人員參與。此計畫建立可靠的流行病學證據和劑量評估，以供未來可進一步的透過適當的眼球劑量計和精密的眼科檢查，為輻射誘發的晶狀體混濁病變提供客觀和定量的評估，並對相關工作人員，提供可提升其輻射防護與降低劑量的作業程序。

（二） 法國政府的因應作為

依據歐盟輻防新指引第 40 條規定，為利進行輻防作業的監測與監督，歐盟會員國需將輻射工作人員分為 A、B 兩類，A 類工作人員為接受之全身有效劑量大於 1 年 6 mSv，或眼球水晶體接受之等效劑量大於 1 年 15 mSv、皮膚和四肢接受之等效劑量大於 1 年 150 mSv 之人員；非屬於 A 類的工作人員即 B 類的工作人員，如圖 29。A 類的輻射工作人員，應進行個別劑量監測，並且如果 A 類工作人員會接受大量的體內曝露或明顯的眼睛或皮膚四肢的曝露，應建立適當的眼球水晶體劑量或皮膚四肢劑量的監測系統。對於對 B 類工作人員，也應進行劑量監測，以證明此類工作人員是被正確劃入 B 類，如有需要，歐盟會員國也可要求對 B 類工作人員進行個人劑量監測。

基於上述規定，ASN 已研擬完成相關法案（勞工法案）之修正草案，除了修訂新的眼球水晶體劑量限值，也將對眼球水晶體的監測劑量計進行規範，預計於 2017 年完成法案修正，2023 年開始全面施行新的眼球水晶體劑量限值。未來將針對新訂定之眼球水晶體劑量限值採實際量測 Hp(3)的方式進行劑量監測，目前包括 ASN 的所屬研究機構 IRSN，與民間公司 LANDAUER 等均已發展出商用的眼球專用劑量計，如圖 30。另外，IRSN 所建立的全國劑量資料庫「Ionizing radiation exposure monitoring information system；Siseri」，也於 2015 年開始記錄輻射工作人員的眼球水晶體劑量監測值，目前（2015 年）有進行眼球水晶體劑量監測的人數很少，全法國僅約 200 人，未來 5-6 年 ASN 將持續宣導眼球水晶體劑量監測事宜。

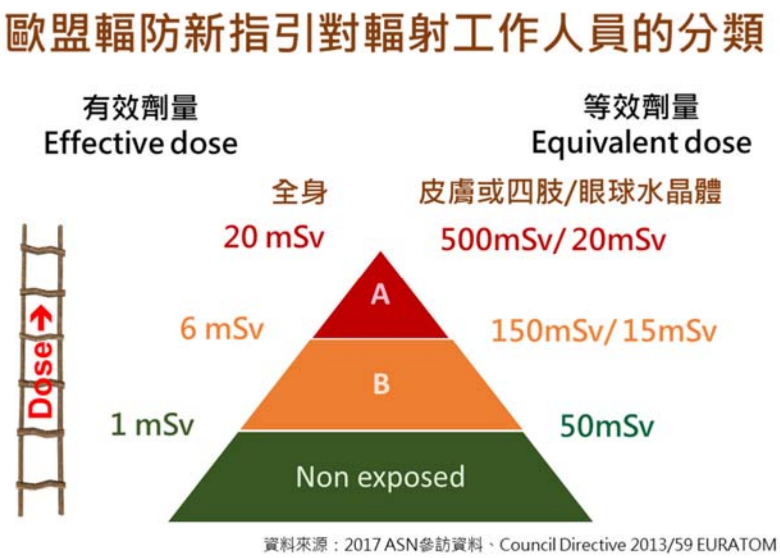


圖 29、歐盟輻防新指引對輻射工作人員的分類

圖 30、IRSN（左圖）與 LANDAUER 公司（右圖）發展出的眼球專用劑量計

伍、心得與建議

一、國際放射防護委員會（ICRP）為世界輻射防護最高的指導專家委員會，其提出的建議為各國輻防作業所遵循的目標，透過參與會議，聆聽演講者的分享與收集相關資料，有助於了解最新的輻防趨勢，掌握輻防管理方向，相關的經驗分享都可作為我國輻防管制的參考。藉由參加國際會議也體悟到，輻射防護沒有最好，只有更好，相關的管制措施與管理思維惟有不斷的精進，才能與時俱境，讓我國輻射防護水平與國際接軌，更加保障人民的安全。

二、藉由實際走訪國際組織（NEA），能對國際事務的推展有更進一步的認識。而與法國輻射安全管制機構 ASN 的資深顧問晤談，更能瞭解法國在輻防實務管制的做法，吸取法國在推動 ICRP 新建議（ICRP-103 號報告）的經驗，可作為我國規劃精進輻防法規的參考。雖然在未來輻防法規的修正或輻防作業的管制上，仍須進一步考量我國國情，但收集此等先進國家的管制方法與修法經驗，瞭解國際輻防新趨勢，對於未來推動輻射防護政策與進行管制都有許多幫助，建議未來有機會持續派員參加類似國際會議，以及赴國外相關機構參訪討論。

三、環境的輻射防護議題是 ICRP 會近年來持續努力的目標，亦循序漸進的將一開始僅有理論的環境輻射防護概念，發展出相關的操作工具，雖然目前尚未有具體可行的建議與指引，但建議本會可持續的關注此項議題的發展，例如動物醫療的輻射防護，必定也是未來重要的發展方向。

四、核子事故的緊急應變機制在 2011 年日本福島事故後有巨大的改變，不僅日本政府，世界各國與相關的國際組織（如 IAEA）均非常積極的檢討現有的應變機制或標準，我國在 2011 年底即完成「國內核能電廠現有安全防護體制全面體檢方案」，其中針對核子事故後的緊急應變機制亦有全盤的檢討與精進，目前相關的精進措施仍持續進行。藉由吸取日本福島事件後的疏散經驗，瞭解日本政府現行做法，有助於在精進相關的規範與程序，以及未來在決策端與執行面上能更加周延。未來，仍建議持續收集其他國家的核子事故緊急應變規範與實務做法，亦可借鏡其他災害的處置經驗，使我國在核子事

故及其他輻射災害的應變上能更為完善。

五、ICRP-103 號報告如何落實於國內法規與實務執行，一直是各國輻防管制機構，也是本會所關注的議題。惟 ICRP-103 號報告為原則性的建議，不易直接納入國內法規施行，一般來說，各國會再參考國際原子能總署與歐盟的規範。而依據 ICRP-103 號報告所完成的 IAEA 的新標準（IAEA GSR Part 3）與歐盟新指引（Council Directive 2013/59 EURATOM）也已於 2013-2014 年發布。歐盟國家，如法國、英國、德國等，正在進行相關法規檢討與修正作業。為與國際接軌，建議可參考本次職參訪 ASN 所帶回之法國經驗，研擬如何將 ICRP 的輻防新建議納入游離輻射防護法規中，建議可先訂出相關法規的修訂目的、方向、修訂順序，相關配套措施，再依規劃執行，以利修法作業遂行。

六、針對輻射工作人員眼球水晶體劑量限值新建議，因對於部分輻射工作人員（如從事介入性診療之醫師）可為更加的輻射防護，建議可規劃相關法規（游離輻射防護安全標準）修訂事宜。考量眼球水晶體劑量限值的修訂涉及劑量的監測，其監測方式、監測對象，以及劑量計的校正、人員劑量評定機構與全國輻射工作人員劑量資料庫之配合，均須整體納入規劃與考量。

陸、致謝

本篇報告之專題內容係來自 ICRP 第四屆國際輻射防護體系研討會（ICRP-ERPW 2017）的報告資料，感謝相關作者提供之摘要與簡報，另外感謝 ASN 的 Chantal BARDELAY 女士的熱心接待與接受訪問，並提供相關資訊，以及 ASN 的 Michel BOIVINEAU 的參訪安排。也要特別感謝本會派駐法國代表處科技組林副組長兼駐 OECD/NEA 顧問的積極安排與協助，本次參訪才能順利完成，在此特別致謝。最後，感謝曾經協助職本次行程順利成行的所有長官與同仁，因為你們的支持，本次出國方能順利圓滿。

柒、附件

第四屆國際輻射防護體系研討會（ICRP-ERPW 2017）會議議程與摘要。

ICRP

4TH INTERNATIONAL SYMPOSIUM ON THE SYSTEM OF RADIOLOGICAL PROTECTION

October 10-12 2017, Paris, France

ERPW

2ND EUROPEAN RADIOLOGICAL PROTECTION RESEARCH WEEK

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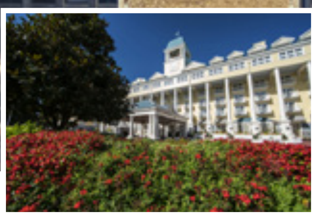

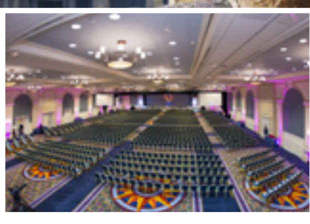

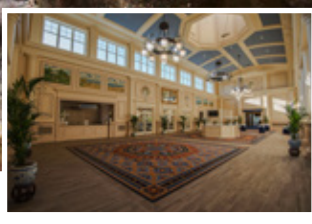

MELODI

EUROPEAN RADIOECOLOGY ALLIANCE

EURADOS

NERIS

EURAMED
European Alliance for Medical Radiation Protection Research

Content

Welcome Messages

From IRSN Director General

Jean-Christophe Niel
IRSN Director General

It is a great honour for IRSN to host ICRP's 4th International Symposium on the System of Radiological Protection, and the 2nd European Radiological Protection Research Week. This combined event will be a great opportunity for researchers, experts and professionals worldwide to share their current works and concerns and also to reflect together about the future challenges of radiological protection. IRSN is fully mobilized to ensure the success of ICRP 2017 and ERPW!

I express my sincere thanks to my French and European colleagues who already dedicated time and efforts in helping organise this unique and important event, and to all supporting organisations in Europe and worldwide for making it possible.

From ICRP Chair

Claire Cousins
ICRP Chair

Our series of International Symposia on the System of Radiological Protection is the cornerstone of our priority to engage with professionals, policy-makers and the public. Having held these symposia in North America, the Middle East, and Asia, the Commission responded enthusiastically to the offer of the MELODI Chair to organise our next International Symposium, ICRP 2017, in Paris in conjunction with the annual 'rendez-vous' of European researchers, supported by the experience and expertise of the French Institute of Radiological Protection and Nuclear Safety.

I have no doubt that this exceptional event will contribute to the promotion of the System of Radiological Protection.

From Platforms

Jacques Repussard
MELODI Chair
on behalf of the Platforms

MELODI (low dose effects) and fellow platforms: ALLIANCE (radioecology), EURADOS (dosimetry), EURAMED (medical applications), NERIS (emergency preparedness) are working together to integrate European research and enhance the robustness of European radiation protection. They develop and implement strategic research agendas and long term research roadmaps which are discussed, in the light of recent scientific results, at their unique open yearly rendez-vous, the European Radiological Protection Research Week.

I am extremely pleased that the 2017 Paris edition will be held in conjunction with ICRP, thus augmenting interactions between research and its stakeholders.

Organisation

2nd European Radiation Protection Research Week

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46 quai Alphonse Le Gallo 92100 Boulogne-Billancourt France
www.oecd-nea.org

The Nuclear Energy Agency (NEA) is a specialised agency within the Organisation for Economic Co-operation and Development (OECD), an intergovernmental organisation of industrialised countries, based in Paris, France.

The objective of the NEA is to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally sound and economical use of nuclear energy for peaceful purposes. It provides authoritative assessments and forges common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD analyses in areas such as energy and the sustainable development of low-carbon economies.

The NEA Committee on Radiological Protection and Public Health (CRPPH) has been addressing issues since 1957 as requested by member country radiological protection regulatory authorities. Within its mandate to assist members to most effectively protect the public, workers and the environment from the risks of exposure to ionising radiation, the CRPPH has over the years addressed a broad variety of radiological protection policy, regulation, operation and science subjects (see CRPPH publications).

In achieving its work, the CRPPH has liaised closely with the ICRP, providing in particular multi-national regulatory input to the development of ICRP guidance on radiological protection principles. CRPPH efforts during the development of the latest ICRP general recommendations (ICRP Publication 103 in 2007) included seven CRPPH expert group reports, seven international workshops and four detailed reviews of ICRP draft materials. The CRPPH process for review and comment on ICRP draft materials consists of a thorough assessment of text addressing regulatory concerns. This CRPPH assessment process continues as relevant ICRP draft reports arrive at the external body comment phase.

The CRPPH has also been working with the ICRP to support a series of stakeholder dialogue initiative symposia that "give voice" to individuals living in affected areas. From these initiatives, the CRPPH has learned many significant lessons applicable to recovery planning and preparation, in particular. The NEA also co-operates with a range of multilateral organisations, including the European Commission and the International Atomic Energy Agency.

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2 place Maurice Quentin 75039 Paris Cedex 01 France
https://cnes.fr/en

CNES supports the radiation biology research.

Space radiation elicit one a very complex spectrum of particles and rays differing by type, energy, doses and dose rates, which renders difficult the evaluation of risks linked to exposure to space radiation. Particularly, cosmos, sun and Van Allen belt produce electrons, protons and some heavy ions together with a continuous background of X-rays. By omitting the solar particle events, the average exposure to radiation in space is ≈ 0.4 mSv/day, 146 mSv/year. (On Earth, the natural radiation background varies from 0.5 mSv/year (Japan) to more than 70 mSv/year (e.g. Ramsar, Iran). Hence, while space radiation are known to cause cataracts and may induce radiation-induced cancers, they raise similar questions than radiotherapy and radiodiagnosis consequences: influence of dose-rate and energy, occurrence of specific low-dose effects, biological efficiency of charged particles, development of efficient radioprotection countermeasures, differences in radiosensitivity between organs and impact of individual radiosensitivity. The French National Space Agency (CNES) fully supports radiobiology research throughout basic research programs and experiments in ISS or in stratospheric balloons, in order to better understand the mechanisms of radiation response in general and to evaluate the risk of each space mission in particular.

Supporter Information

Office of Environment, Health, Safety and Security
An office of the US Department of Energy

Forrestal Building U.S. Department of Energy 1000 Independence Ave., S.W. Washington, DC 20585 USA
https://energy.gov/ehss/environment-health-safety-security

The United States Department of Energy's (U.S. DOE) Office of Environment, Health, Safety and Security (AU) is responsible for providing leadership to coordinate and integrate the health, safety, environment and security programs across the U.S. DOE complex.

The Office of Health and Safety (AU10) within AU establishes worker safety and health requirements and expectations for the Department to ensure protection of workers from the hazards associated with Department operations. AU10 supports domestic health studies to determine worker and public health effects from exposure to hazardous materials associated with Department operations. AU10 is also responsible for providing support to international health studies and programs in Japan and the Russian Federation; implementing medical screening and environmental monitoring in the Marshall Islands; and medical surveillance and screening programs for current and former workers, and support the U.S. Department of Labor in the implementation of the compensation program for energy workers. Additionally, AU10 provides assistance to Headquarters and field elements in implementation of policy and resolving worker safety and health issues.

Domestically, AU10's commitment is made visible through an aggressive program to provide scientific evidence and information on the state of health of workers in a cross-section of DOE facilities. Internationally, AU10 is responsible to Congress for managing nuclear legacy issues and to the Executive Branch through DOE for international scientific agreements in several countries. The results from the Radiation Effects Research Foundation and Russian programs are the primary basis for the world-wide radiation protection standards. They are important to the well-being of U.S. DOE and nuclear industry workers, and for compensation issues.

Agence Nationale pour la Gestion des Déchets

1-7 rue Jean Monnet Parc de la Croix Blanche 92298 Châtenay-Malabry France
www.andra.fr

Andra is a public establishment in charge of the long-term management of radioactive waste generated in France. As part of this task, Andra makes its expertise and know-how available to the government with a view to identifying, implementing and guaranteeing safe management solutions for all French radioactive waste, thereby protecting present and future generations from the associated risks.

The agency performs its mission through various activities:

- Operating two existing surface disposal facilities in the Aube department
  - the CSA waste disposal facility for low-level and intermediate-level short-term waste (LILW-SL),
  - the Cires waste collection, storage and disposal facility for very low-level waste (VLLW).
- Monitoring the CSM waste disposal facility (Manche department), the first surface disposal facility for low-level and intermediate-level radioactive waste in France, which is now closed.
- Studying and designing disposal solutions for the types of waste that currently lack a disposal solution, namely:
  - low-level long-lived waste (LLW-LL),
  - high-level waste (HLW) and intermediate-level long-lived waste (ILW-LL): the Cigeo project.
- Providing a public service by :
  - collecting old radioactive objects that are in the hands of individuals (old luminous clocks, radium objects for medical use, natural salts for laboratory work, certain minerals, etc.);
  - cleaning up sites that have been contaminated with radioactivity such as Marie Curie's old laboratories;
  - producing, every three years, the National Inventory of radioactive materials and waste on French soil www.inventaire.andra.fr.
- Informing and promoting dialogue with all audiences
- Preserving the memory of its sites

Sharing and promoting Andra's expertise internationally

Bronze Supporters

Ligue contre le Cancer

14 rue Corvisart 75013 Paris France
www.ligue-cancer.net / facebook.com/laliguecontrelecancer / twitter.com/laliguecancer

The French League against cancer

First French NGO & nonprofit funder for research against cancer, the French League against cancer relies on the commitment of its volunteers & the generosity of the public.

With 650 000 members, the League is a popular movement organized into a federation of 103 departmental Committees. Together, they fight against cancer throught 4 missions: research to cure, prevent to protect, support to help, defending equal rights in healthcare.

Autorité de Sûreté Nucléaire

15 rue Louis Lejeune - CS 70013 92541 Montrouge Cedex France
www.asn.fr

As an independent Body, since 2006, ASN, thanks to a workforce of 500 people, support the government with the drafting of regulations (decrees and ministerial orders), or by issuing technical statutory resolutions.

ASN examines all individual licensing applications concerning facilities or activities. ASN also monitors compliance with the rules and requirements applicable to the facilities (2,000 inspections per year). In addition, ASN informs the public and other stakeholders the state of nuclear safety and radiation protection. And finally, ASN verifies the steps taken by the licensee to make the facility safe.

Consejo de Seguridad Nuclear

c/ Pedro Justo Dorado Dellmans, 11 28040 Madrid Spain
www.csn.es

The Spanish Nuclear Safety Council (CSN) is the only competent authority in Spain regarding nuclear safety and radiation protection.

The CSN's mission is to protect workers, the public and the environment from the harmful effects of ionising radiation, ensuring that nuclear and radioactive facilities are operated safely by their licensees and establishing the preventive and corrective measures in case of radiological emergencies, no matter what their source is.

The CSN's most important activity in the field of multilateral international relations is its involvement in the governing bodies, committees and working groups of various international organisations, such as the International Commission on Radiological Protection (ICRP), to which the CSN contributes actively with experts and financially.

EDF

22-30 avenue de Wagram 75382 PARIS Cedex 08 France
www.edf.fr

Nuclear safety is the number one priority of EDF Group, as a responsible operator of the 58 nuclear power generation units in France.

Nuclear safety relates to all technical, human and organisational measures implemented at every step in the operation of a nuclear power plant, and designed to protect the population and the environment against any potential dispersal of radioactive substances in all circumstances.

The foundations of nuclear safety rely on appropriate safety management and a safety culture based on enforcement of stringent procedures and ongoing training. Nearly 3 million hours of training were delivered in 2016, i.e. 50% of the full training volume at EDF SA, and a 30% increase over the past 6 years.

Radioprotection of all operating staff likely to be exposed to ionizing radiations in nuclear power plants is a key priority for EDF. Whether employed directly by EDF or by its subcontractors, all workers benefit from identical conditions of radioprotection and medical follow-up. The ultimate goal is to ensure that radiation exposure remains as low as possible for everyone.

Supporter Information

SAPHYMO – Bertin Instruments

10 bis avenue Ampère 78180 Montigny le Bretonneux France

www.bertin-instruments.com

Based on Saphymo's strong expertise, Bertin Instruments has developed and optimized nuclear equipment to provide state-of-the-art instrumentation.

Its Radioactivity product range is entirely dedicated to the detection and monitoring of ionizing radiation (alpha, beta, gamma and neutron) and spans a wide range of applications relating to the protection of individuals, systems and the environment : Dosimetry systems (measuring doses absorbed by people exposed to ionizing radiation), Contamination monitors (monitoring the contamination levels of people, objects and soil), Access control / Clearance monitors (for radiological controls on pedestrians, loads and vehicles), Radiation monitoring Systems (monitoring radiation inside facilities), Environmental Radiation Monitoring Systems & Networks (monitoring radiation in air, water and soil), Survey meters (control and analysis devices).

MIRION TECHNOLOGIES

Route d'Eyguières 13113 Lamanon France

www.mirion.com

Innovation Making a Difference in Radiation Safety, Sciences and Exploration

Mirion Technologies is a leader in the measurement, detection and monitoring of radiation. We develop innovative products, systems and services used to secure critical facilities, protect people from radiation exposure and limit the spread of contamination. Mirion solutions are also employed in cutting-edge research and for scientific exploration in the most remote locations on Earth, underground, and in deep space.

Our customers around the world operate in facilities with exacting standards for safety, reliability and defensibility of results. Day in and day out, we work to maintain their trust by providing high value, high quality solutions that enhance their operations.

The Health Physics Division of Mirion Technologies designs, develops and sells:

- Handheld instruments
- Electronic/Passive Dosimetry & Telemetry devices
- Contamination control monitors
- Military instruments
- Area monitors
- Search and Identification equipment

GE HEALTHCARE

www.gehealthcare.com

GE Healthcare provides transformational medical technologies and services to meet the demand for increased access, enhanced quality and more affordable healthcare around the world. GE (NYSE: GE) works on things that matter - great people and technologies taking on tough challenges.

From medical imaging, software & IT, patient monitoring and diagnostics to drug discovery, biopharmaceutical manufacturing technologies and performance improvement solutions, GE Healthcare helps medical professionals deliver great healthcare to their patients. For more information about GE Healthcare, visit our website at www.gehealthcare.com.

Nuvia

280 avenue Napoléon Bonaparte 92500 Rueil-Malmaison France

http://nuvia-group.com/en/

The NUVIA Group prides itself in working collaboratively with its customers at all stages of a nuclear facility's life cycle: design, construction, operations, maintenance, decommissioning. We deliver our expertise through three complementary activities: Engineering - Services and Works - Products.

Our activities cover civil engineering, mechanics, waste management, radiation protection including nuclear measurement, fire and flood protection.

NUVIA operates at all stages, from the design to the construction of nuclear facilities: in engineering, as a specialised partner, with a wide range of specific products (facility protection against fire, earthquake, flood, dissemination and radiological risks) or as a global integrated contractor, delivering turnkey projects.

NUVIA provides operations and industrial contractor services on all categories of nuclear facilities. We also supply our clients with an array of support services, among which are radioprotection, security and safety, handling, logistics and waste management. We offer an extensive range of products and technical expertise to help you optimise maintenance operations as far as costs, deadlines and safety are concerned.

NUVIA offers a complete catalogue of components (analysers, detectors, software), as well as equipment systems specifically designed for waste management, homeland security, environmental monitoring, continuous process monitoring, health physics and laboratories.

NUVIA is present in: France, United Kingdom, Italy, China, India, Canada, Czech Republic, Slovakia, Germany, Sweden and USA, with a workforce of 2 700 employees and an annual revenue of Ð345 m, in 2016. Our teams of specialists guarantee a level of excellence with a mastery of safety and security.

Belgian Nuclear Research Centre

Boeretang 200 2400 Mol Belgium

www.sckcen.be

SCK•CEN is one of the largest research institutions in Belgium. Every day, more than 700 employees dedicate themselves to developing peaceful applications of radioactivity.

Our developments have already resulted in a long list of innovative and forward-looking applications for the medical world, industry and the energy sector. We are renowned for our expertise worldwide.

As a foundation of public utility, the Belgian Nuclear Research Centre conducts groundbreaking research into nuclear energy and ionising radiation for civilian use, and develops nuclear technologies for socially valuable purposes. We achieve this by means of independent, fundamental and applied research, and by providing advice, training, services and products.

Institut national des sciences et techniques nucléaires

Centre CEA 91191 Gif-sur-Yvette France

www-instn.cea.fr

INSTN, the National Institute for Nuclear Science and Technology is a higher education and national training institution, administered by the CEA (french atomic energy and alternative energies commission).

For 60 years, INSTN have been providing highly specialised teaching and training courses, at all levels – from entry level technician to researcher – based on science and technology for nuclear applications, such as nuclear energy, as well as its industrial and medical applications.

Our main mission is to contribute to skills development of individuals in order to improve performance and increase competitiveness of companies in these sectors.

We make sure to adapt INSTN's offer to our clients' developing needs, working in partnership with other academic and industrial institutions in France and abroad. In 2016, INSTN was designated a 'Collaborating Centre' of the International Atomic Energy Agency (IAEA) for education and training in nuclear technologies, as well as industrial and radiopharmaceutical applications, for a period of four years. INSTN is the first such IAEA 'Collaborating Centre' in France and Europe in these fields. This recognition supports companies using INSTN's services, in particular in their international programmes.

Supporter Information

LANDAUER Europe

9 rue Paul Dautier CS 60731 78457 Velizy-Villacoublay Cedex France

http://landauer.eu

LANDAUER, the worldwide leader in passive dosimetry, ensures accurate personnel monitoring and precise dose measurements in any environment where there is potential exposure to ionising radiations.

We provide integrated radiation safety products and services to hospitals, medical and dental practices, universities, national laboratories, and other industries in which radiation poses a potential threat to employees.

The service includes the manufacture of various types of radiation detectors (OSL, TLD and CR-39), the distribution and collection of dosemeters to and from clients, the analysis, reporting and record keeping of personal doses.

With over 60 years of continuous industry service, LANDAUER is a reference in radiation safety, commitment to innovation and client support. Our objective is to combine technologies and services to create the right monitoring programme for any exposure environment.

LANDAUER | Setting the Pace of Radiation Safety™

The European Organization for Nuclear Research

CH-1211 Geneva 23 Switzerland

http://home.cern/about

An intergovernmental organisation with 22 Member States, CERN's mission is research: pushing the frontiers of science for the benefit of all. Headquartered in Geneva, CERN straddles the French-Swiss border and attracts over 12 000 scientists from around the world with collaborations ranging from a handful to teams of thousands.

A leader in its field, CERN is committed to excellence in all that it does. Its diverse and dynamic research environment, along with 45km of Radiation Areas, makes for challenging radiation protection. By developing creative new techniques CERN strives to be a role model in this area.

European Nuclear Safety Training & Tutoring Institute

12 rue de la Redoute 92260 Fontenay-aux-Roses France

www.enstti.eu

Experts for experts: ENSTTI proposes training in nuclear safety, nuclear security and radiation protection

The European Nuclear Safety Training and Tutoring Institute, ENSTTI, is an initiative of the European Technical Safety Organizations Network-ETSON. It was set up in 2010 to develop and provide high-quality training programs to meet the needs of experts at nuclear regulatory bodies and TSOs; to ensure the continuous development of qualified experts in this area; and to foster harmonization of technical practices in nuclear safety, nuclear security and radiation protection. This is achieved through the regular provision of vocational training and tutoring exclusively delivered by senior professionals from European TSOs that take into consideration latest technical developments. ENSTTI has structured its training programs directed at professionals in nuclear and radiation related industries and activities in integrating radiation safety and nuclear safety concepts. ENSTTI has earned recognition and backing from the European Commission and international organizations, starting with the IAEA. It is commissioned more and more to provide training and tutoring outside of the European Union.

More on our training programs at www.enstti.eu

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs DHA
Federal Office of Public Health FOPH

Federal Office of Public Health

Schwarzenburgstrasse 157 3003 Bern Switzerland

https://www.bag.admin.ch/bag/en/home.html

The Federal Office of Public Health (FOPH) provides competence in healthcare, promotes a healthy lifestyle and works for the general well-being of the public.

It develops Switzerland's health policy and is responsible for more than twenty laws including the radiological protection act. As radiological protection competent authority, the FOPH aims to ensure that the health of the public, patients and workers, as well as the environment, are protected against the dangers of ionising radiation. It issues licences for the use of ionising radiation in medicine, industry (except nuclear industry) and research. It supervises, controls and supports the regulatory implementation in medicine and research. The FOPH is in charge of monitoring the radioactivity in the environment and conducting the national radon action plan. It is also involved in organising the preparedness and response to radiological emergencies. In addition, the FOPH contributes to informing the public about any health issues related to both ionising and non-ionising radiation.

Société Française de Radioprotection

2 rue de la Redoute 92263 Fontenay-aux-Roses France

www.sfrp.asso.fr

Société française de radioprotection (SFRP) is a non-profit organisation founded in 1965.

It is composed of nearly 1,300 members who are professionals specialising in Radiation protection : Members include engineers, researchers, developers, technicians, physicians, inspectors, profesors and educational staff, students, pensioners... engaged or having an interest in the protection of the various fields of activity concerned by ionising and non-ionising radiations.

For 50 years, the association's objectives have been to share the experience and practices between professionals, to encourage exchanges of information between specialists and nonspecialists, to promote the culture of radiation protection. Its purpose is also to disseminate information to the different non-professional actors who are involved in radiation protection. In this purpose, SFRP organizes national congress, topical days and round tables (5 or 6 per year).

Affiliated to International Radiation Protection Association (IRPA), SFRP participates to international exchanges and organizes workshops with other foreign radiation protection societies.

Commissariat à l'Energie Atomique et aux Energies Alternatives

CEA siège 91191 Gif-sur-Yvette Cedex France

www.cea.fr

The French Alternative Energies and Atomic Energy Commission (CEA) is a key player in research, development and innovation in four main areas:

- defence and security,
- nuclear and renewable energies,
- technological research for industry,
- fundamental research in the physical sciences and life sciences.

Drawing on its widely acknowledged expertise, the CEA actively participates in collaborative projects with a large number of academic and industrial partners.

The CEA is established in nine centers spread throughout France. It works in partnership with many other research bodies, local authorities and universities. Within this context, the CEA is a stakeholder in a series of national alliances set up to coordinate French research in energy (ANCRE), life sciences and health (AVIESAN), digital science and technology (ALLISTENE), environmental sciences (AllEnvi) and human and social sciences (ATHENA).

Supporter Information

Associazione Italiana Di Fisica Medica

Piazza della Repubblica, 32 20124 Milan Italy

www.fisicamedica.it/ and on Facebook, Twitter and LinkedIn

Italian Association of Medical Physicists (AIFM) represents more than one thousand medical physicists working in Health Care, Academia and Research Institutes.

AIFM aims at endorsing scientific knowledge and professional practice of medical physics, which is a regulated health profession. The radioprotection of patients, healthcare professionals and citizen is one of its priority tasks.

AIFM acts as Provider of Continuous Professional Education in Medicine organizing numerous educational opportunities. In particular, the Superior School in Physics in Medicine "Piero Caldirola" of AIFM organizes several courses proposed by members and prioritized by the AIFM Scientific Committee.

In addition, AIFM founded the School of Radioprotection in Health Care sector. AIFM promotes a platform for the improvement of professional skills in the area of medical physics and radiological protection and has established a research commission for identifying and facilitating the funding opportunities.

Canadian Nuclear Safety Commission

280 Slater Street, P.O. Box 1046, Station B Ottawa, ON K1P 5S9 Canada

www.nuclearsafety.gc.ca/eng/

The Canadian Nuclear Safety Commission (CNSC) was established in 2000 under the Nuclear Safety and Control Act (NSCA) to replace the former Atomic Energy Control Board (AECB).

Under the NSCA, the CNSC's mandate involves four major areas:

- regulation of the development, production and use of nuclear energy in Canada to protect health, safety and the environment;
- regulation of the production, possession, use and transport of nuclear substances, and the production, possession and use of prescribed equipment and prescribed information;
- implementation of measures respecting international control of the development, production, transport and use of nuclear energy and substances, including measures respecting the non-proliferation of nuclear weapons and nuclear explosive devices; and
- dissemination of objective scientific, technical and regulatory information concerning the activities of CNSC.

The CNSC's Commission Tribunal has up to seven appointed permanent members whose decisions are supported by a CNSC staff of 850 persons.

Korean Association for Radiation Protection

Hanyang Institute of Technology Bldg. 222 Wangsimni-ro, Seoungdong-gu 04763 Seoul Korea

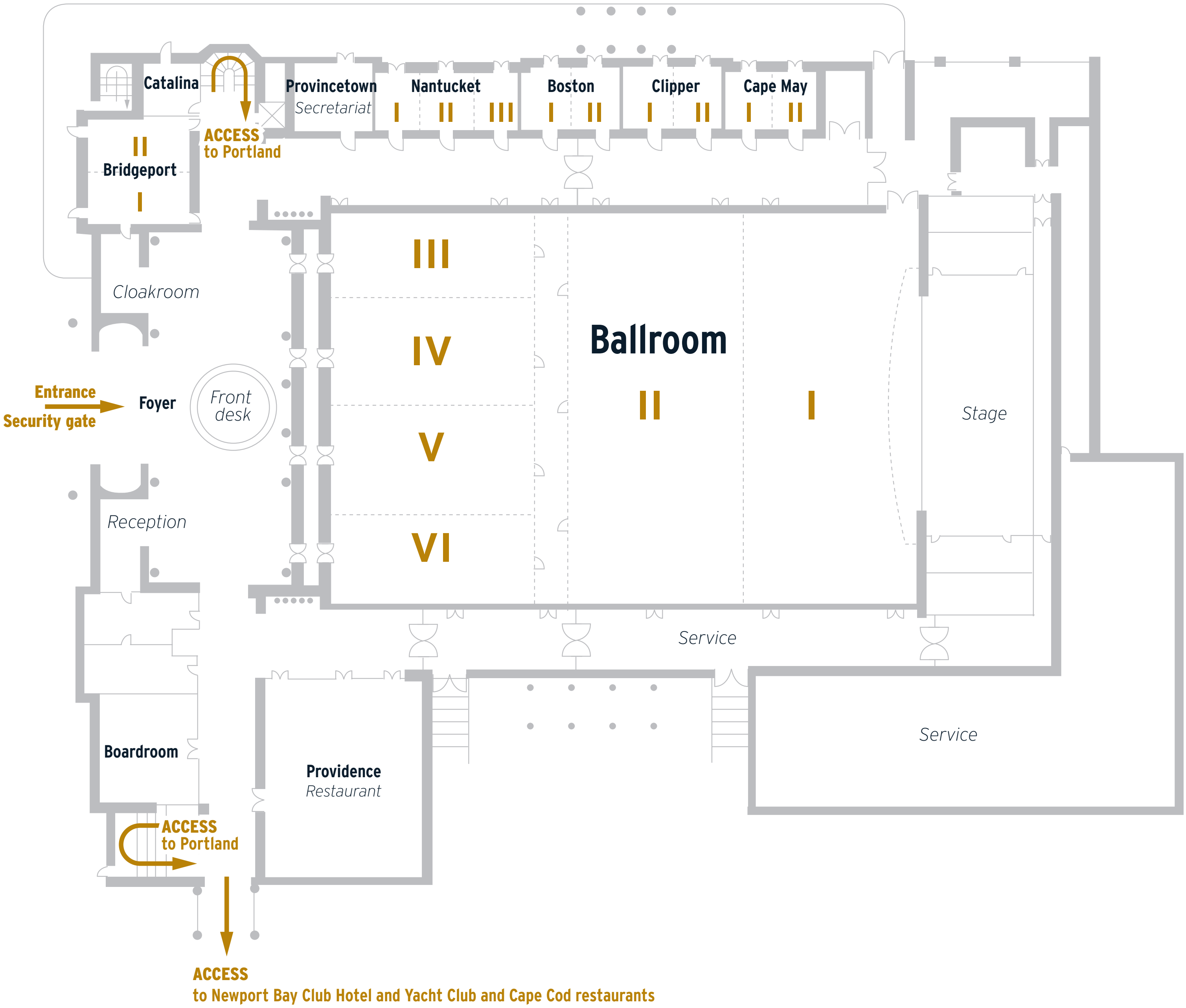
www.karp.or.kr/en

The Korean Association for Radiation Protection (KARP) has played a key role in leading academic societies to achieve the objective of radiological protection and to keep the safety of radiation workers and the general public in Korea.

With engagements of activities with international organizations such as ICRP, IRPA, AOARP, and UNSCEAR, KARP would like to expand its responsibility for sharing the experience and knowledge to further advance the required science and technology for radiological protection.

Meeting Spaces

The Portland Exhibition Hall (posters, booths and coffee breaks) is one floor lower and accessible by stairs & lifts.



Programme at a Glance

Time	Tuesday October 10		Wednesday October 11
9:00 – 10:30	*WELCOME BREAK*		**ICRP & MELODI** *Session* Effects, Risks, and Detriment at Low Dose and Low Dose-Rate *Ballroom I, II*
10:30 – 11:00	*OPENING CEREMONY* *Ballroom I, II*		*COFFEE BREAK* *Portland*
11:00 – 12:30			**ICRP & MELODI** *Session* Effects, Risks, and Detriment at Low Dose and Low Dose-Rate *Ballroom I, II*
12:30 – 14:00	*LUNCH* *Cape Cod & Yacht Club & Providence*		*LUNCH* *Cape Cod & Yacht Club & Providence*
14:00 – 15:30	**ICRP & EURADOS** *Session* Advances in Dose Coefficients *Ballroom I, II*	**ERPW** *Session 1* Ethics in Radiation Protection *Ballroom III, IV, V, VI*	**ICRP & EURAMED** *Session* Advanced Radiotherapy: Benefits and Radiation Protection due to Developments in Imaging, New Technologies, and Stratification *Ballroom I, II*
15:30 – 16:00	*COFFEE BREAK* *Portland*		*COFFEE BREAK* *Portland*
16:00 – 17:30	**ICRP & EURADOS** *Session* Advances in Dose Coefficients *Ballroom I, II*	**ERPW** *Session 2* Management of Emergency and Post-accident Situations: How to Optimise Population Evacuation Zones and Related Decision Making Processes? *Ballroom III, IV, V, VI*	**ICRP & EURAMED** *Session* Advanced Radiotherapy: Benefits and Radiation Protection due to Developments in Imaging, New Technologies, and Stratification *Ballroom I, II*
18:00 – 19:30	*RECEPTION* *Foyer*		
19:30 – 20:00			*COCKTAIL* *Dome*
20:00 –			*GALA DINNER* *Dome*

The exhibition and the ERPW poster sessions (Portland) are open :
Tuesday October 10, **8:30** - **19:00** • *Wednesday October 11,* **8:30** - **19:00** • *Thursday October 12,* **8:30** - **17:00**

Wednesday October 11

ERPW *Session 3*
Why is Radioecology an Essential Science when Analyzing Human Population Exposure?
Ballroom III, IV

ERPW *Session 4*
Benefit vs Risk in Diagnostic and Interventional Radiology, Nuclear Medicine, and Radiotherapy
Ballroom V, VI

COFFEE BREAK
Portland

ERPW *Session 5*
Medical Radiation Incidents/Accidents
Ballroom III, IV

ERPW *Session 6*
Internal Dosimetry
Ballroom V, VI

LUNCH
Cape Cod & Yacht Club & Providence

ERPW *Session 7*
What are the Evidences for Trans/Multigenerational Radiation-Induced Effects and are They of Concern?
Ballroom III, IV

ERPW *Session 8*
Biomarkers and Cohorts Suitable for Exploring Low-Dose/Low-Dose-Rate Exposure Effects and Individual Susceptibility (Humans, Animals and Plants)
Ballroom V, VI

COFFEE BREAK
Portland

ERPW *Session 9*
Use of Observatory Sites for Integrated Long-Term Research Activities
Ballroom III, IV

ERPW *Session 10*
Harmonization of Practices Enabling Patient Dose Repositories
Ballroom V, VI

ERPW *Session 11*
Radioactive Iodine: Gaps and Knowledge Needed for Nuclear Crisis Integrated Management
Ballroom III, IV

ERPW *Session 12*
Dosimetry in Complex Fields
Ballroom V, VI

COCKTAIL *Dome*

GALA DINNER *Dome*

Thursday October 12

9:00

ICRP & NERIS *Session*
Post-Accident Recovery
Ballroom I, II

ERPW *Session 13*
Eye Lens Exposure and Monitoring
Ballroom III, IV, V, VI

9:30
10:00
10:30

COFFEE BREAK
Portland

11:00

ICRP & NERIS *Session*
Post-Accident Recovery
Ballroom I, II

ERPW *Session 14*
Individualized Approaches for Radiation Protection
Ballroom III, IV, V, VI

11:30
12:00
12:30

LUNCH
Cape Cod & Yacht Club & Providence

13:00
13:30

ICRP & ALLIANCE *Session*
Integrated Protection of People and the Environment
Ballroom I, II

14:00

MELODI Award Ceremony
Ballroom III, IV, V, VI

14:30
15:00

COFFEE BREAK
Portland

15:30

ICRP & ALLIANCE *Session*
Integrated Protection of People and the Environment
Ballroom I, II

ERPW
Summary
Ballroom III, IV, V, VI

16:00
16:30
17:00

ICRP & ERPW
SUMMARY AND CONCLUDING REMARKS
Ballroom I, II

17:30
18:00
19:30
20:00

Programme Schedule

MONDAY OCTOBER 9

08:00 - 18:00 **REGISTRATION** *Front desk*

TUESDAY OCTOBER 10

08:00 - 18:00 **REGISTRATION** *Front desk*

08:30 - 19:00 **EXHIBITION AND POSTER SESSIONS** *Portland*

10:30 - 12:30 OPENING CEREMONY *BALLROOM I, II*

Jean-Christophe Niel,
Director General of IRSN

Claire Cousins,
Chair of ICRP

Jacques Repussard,
on behalf of the European Platforms

Daniel Iracane,
Deputy Director General of OECD/NEA

Émilie Cariou,
Member of French Parliament & OPECST

12:30 - 14:00 **LUNCH** *Cape Cod & Yacht Club & Providence*

14:00 - 15:30
EURADOS & ICRP SESSION:
Advances in Dose Coefficients

Ballroom I, II
Co-Chairs: Volodymyr Berkovskyy (ICRP C2, EURADOS WG 7, Ukraine), Jean-François Bottollier-Depois (EURADOS WG11, France)

14:00 Introductory Presentation: The Mandate and Work of ICRP Committee 2 on Dose from Radiation Exposure
John Harrison (ICRP MC & C2 Chair, UK)

14:15 Introductory Presentation: The Work Programme of EURADOS on Internal and External Dosimetry
Werner Rühm (EURADOS, Germany)

14:30 Computational Phantoms, ICRP/ICRU and Further Developments
Maria Zankl (EURADOS WG6, Germany)

15:00 New Mesh-type Phantoms and their Dosimetry Applications Including Emergencies
Chan Hyeong Kim (ICRP C2, Korea)

14:00 - 15:30
ERPW SESSION 1:
Ethics in Radiation Protection

Ballroom III, IV, V, VI
Co-Chairs: Gaston Meskens (SCK•CEN, Belgium), Marie Claire Cantone (University of Milan, Italy)

14:00 A broader set of ethical principles, or values, for radiation protection
Friedo Zoelzer (University of South Bohemia, Czech Republic)

14:20 Health surveillance and management of populations affected by a radiation accident - can ethics help?
Deborah Oughton (NMBU, Norway)

14:40 Ethical framework for radiation protection in medicine: scenarios from diagnostic imaging
Jim Malone (St James's Hospital Dublin, Ireland)

14:55 Ethical considerations on the empowerment of people living in contaminated areas after a nuclear accident
François Rollinger (IRSN, France)

15:10 Ethics, optimization, sustainability and radiation protection
Graham Smith (GMS, UK)

15:30 - 16:00 COFFEE BREAK *Portland*

16:00 - 17:30
EURADOS & ICRP SESSION *(continuation)*:
Advances in Dose Coefficients

Ballroom I, II
Co-Chairs: Volodymyr Berkovskyy (ICRP C2, EURADOS WG 7, Ukraine), Jean-François Bottollier-Depois (EURADOS WG11, France)

16:00 ICRP Task Group 95: Internal Dose Coefficients
François Paquet (ICRP C2, France)

16:30 EURADOS Work on Internal Dosimetry
Bastian Breustedt (EURADOS WP7, Germany)

17:00 Panel Discussion

16:00 - 17:35
ERPW SESSION 2:
Management of Emergency and Post-accident Situations: How to Optimise Population Evacuation Zones and Related Decision Making Processes?

Ballroom III, IV, V, VI
Co-Chairs: Damien Didier (IRSN, France), Florian Gering (BfS, Germany)

16:00 Evacuation in nuclear emergency: lessons from Fukushima Daiichi accident
Nobuhiko Ban (NRA, Japan)

16:20 SHAMISEN recommendations and procedures for preparedness and health surveillance of populations affected by a radiation accident
Elisabeth Cardis (ISGlobal, Spain)

16:40 To leave or not to leave? Insights from an empirical study on expected evacuation behaviour
Catrinel Turcanu (SCK•CEN, Belgium)

16:55 Decision making in return to the evacuation zone based on the integrating cancer risk
Hiroshi Yasuda (Hiroshima University, Japan)

17:10 Role of citizen measurements in radiation protection, emergency preparedness and response - its pros and cons
Petr Kuca (SURO, Czech Republic)

18:00 - 19:30 ERPW / ICRP RECEPTION *Foyer*

WEDNESDAY OCTOBER 11

08:00 - 18:00 REGISTRATION *Front desk*

08:30 - 19:00 EXHIBITION AND POSTER SESSIONS *Portland*

09:00 - 10:30
MELODI & ICRP SESSION:
Effects, Risks, and Detriment at Low Dose and Low Dose-Rate

Ballroom I, II
Co-Chairs: Simon Bouffler (ICRP MC, UK), Thomas Jung (MELODI/BfS, Germany)

09:00 Introductory Presentation: The Mandate and Work of ICRP Committee 1 on Radiation Effects
Werner Rühm (ICRP MC & C1 Chair / Helmholtz Zentrum, Germany)

09:15 Introductory Presentation: Outcome of the European Initiative for Radiation Protection Research and Future Perspectives
Jacques Repussard (MELODI, France)

09:30 Evidence for Dose and Dose-rate Effects in Human and Animal Radiation Studies
Mark Little (NIH, USA)

10:00 Cancer Risk from Paediatric CT Scanning: Implications for Radiation Protection in Medicine
Ausra Kesminiene (IARC, France), Elisabeth Cardis (IS Global, Spain)

09:00 - 10:30
ERPW SESSION 3:
Why is Radioecology an Essential Science when Analyzing Human Population Exposure?

Ballroom III, IV
Co-Chairs: Patrick Boyer (IRSN, France) Nicholas Beresford (CEH, UK),

09:00 Artificial neural network for prediction of Sr-90 soil to plant transfer factor
Maria Angelica Wasserman (CNEN, Brazil)

09:15 Comparison of tritium environmental measurement results with air dispersion modeling using Lagrangian Particle Dispersion Model
Benjamin Zorko (Jozef Stefan Institute, Slovenia)

09:30 Dynamic modeling of radionuclide transfer between water and biota to estimate seafood contamination
Bruno Fievet (IRSN, France)

09:45 Sensitivity of the modelling of the transfers of radionuclides in freshwaters to the liquid-solid exchanges
Patrick Boyer (IRSN, France)

10:00 Human food chain modelling within the CONFIDENCE project
Nicholas Beresford (CEH, UK)

10:15 Application of the system of radiological protection of the environment in the IAEA Safety Standards - a position paper
Diego Miguel Telleria (IAEA)

09:00 - 10:30
ERPW SESSION 4:
Benefit vs Risk in Diagnostic and Interventional Radiology, Nuclear Medicine, and Radiotherapy

Ballroom V, VI
Co-Chairs: Ulrike Kulka (BfS, Germany) Christoph Hoeschen (OvGU, Germany),

09:00 Benefit vs. risk in diagnostic and interventional radiology
Reinhard Loose (ICRP)

09:20 Benefit vs. risk in nuclear medicine
Klaus Bacher (Ghent University, Belgium)

09:40 Benefit vs. risk in radiotherapy
Catharine West (University of Manchester, UK)

10:00 Psychosocial analysis of radiation protection in the medical field: perspective for IRSN
Manon Britel (IRSN, France)

10:10 Risk projection in pediatric computed tomography - methods, limits and value for clinical practice
Neige Journy (INSERM, France)

10:20 Age-related biological effects of dental cone-beam CT exposure
Niels Belmans (SCK•CEN, Belgium)

10:30 - 11:00 COFFEE BREAK *Portland*

11:00 - 12:30

MELODI & ICRP SESSION

(continuation):

Effects, Risks, and Detriment at Low Dose and Low Dose-Rate

Ballroom I, II

Co-Chairs: Simon Bouffler (ICRP MC, UK), Thomas Jung (MELODI/BfS, Germany)

11:00 Cancer Risk following Alpha Emitter Exposure: a risk assessment of Task Group 64 of ICRP
Margot Tirmarche (ASN, France)

11:30 Human Radiosensitivity and Prospects for Prediction
Andrzej Wojcik (Stockholm University & ICRP Committee 1)

12:00 Panel Discussion

11:00 - 12:30

ERPW SESSION 5:

Medical Radiation Incidents/Accidents

Ballroom III, IV

Co-Chairs: Guy Frija (University of Paris Descartes, France), Colin Martin (University of Glasgow, Scotland)

11:00 Incidents/accidents in diagnostic and interventional radiology
John Damilakis (University of Crete, Crete)

11:20 Incidents/accidents in nuclear medicine
Klaus Bacher (Ghent University, Belgium)

11:40 Incidents/accidents in radiotherapy
Juliana Toma-Dasu (Karolinska Institute, Sweden)

12:00 Retrospective dose assessment of medical radiation exposure: investigation on the ESR dosimetry of nails
Chryzel Angelica Gonzales (Hiroshima University, Japan)

12:15 An automatable micro-PCC assay for biological dosimetry in cases of large-scale radiation exposures
Georgia Terzoudi (Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety, Greece)

11:00 - 12:30

ERPW SESSION 6:

Internal Dosimetry

Ballroom V, VI

Co-Chairs: Maria Antonia Lopez (CIEMAT, Spain), Augusto Giussani (BfS, Germany)

11:00 Child and adult thyroid monitoring after reactor accident: recommendations from European specialists
David Broggio (IRSN, France)

11:30 Medical aspects of internal dosimetry
Christoph Hoeschen (OvGU, Germany)

12:00 Quantification of uncertainty on lifetime dose assessment for workers occupationally exposed to uranium intakes through a EURADOS intercomparison
Estelle Davesne (IRSN, France)

12:15 Radon dosimetry and lung cancer risk assessment for workers: ICRP's approach
James Marsh (PHE, UK)

12:30 - 14:00 LUNCH *Cape Cod & Yacht Club & Providence*

14:00 - 15:30

EURAMED & ICRP SESSION:

Advanced Radiotherapy: Benefits and Radiation Protection due to Developments in Imaging, New Technologies, and Stratification

Ballroom I, II

Co-Chairs: Pierre Scalliet (former ICRP C3, Belgium), Virginia Tsapaki (EURAMED, Greece)

14:00 Introductory Presentation: The Mandate and Work of ICRP Committee 3 on Radiological Protection in Medicine
Colin Martin (C3 Vice-Chair, UK)

14:15 Introductory Presentation: EURAMED's Vision on Medical Radiation Protection (Research)
Christoph Hoeschen (EURAMED)

14:30 Multimodal Imaging for Dose Planning and its Benefit: the Paradigm of Head & Neck Tumours
Vincent Gregoire (Université Catholique de Louvain, Brussels, Belgium)

15:00 The Need for, and Implementation of, Image Guidance in Radiation Therapy
Geoffrey Ibbott (MD Anderson Center, Houston, Texas, USA)

14:00 - 15:30

ERPW SESSION 7:

What are the Evidences for Trans/Multigenerational Radiation-Induced Effects and are They of Concern?

Ballroom III, IV

Co-Chairs: Nele Horemans (SCK•CEN, Belgium), Christelle Adam-Guillermin (IRSN, France)

14:00 Do changes in oxidative stress response, photosynthesis and whole genome methylation induced in plants exposed to enhanced radiation for multiple generations persist in a transgenerational setup?
Nele Horemans (SCK•CEN, Belgium)

14:25 Investigating chronic low-dose ionising radiation (LDIR) in higher plants: Transgenerational effects on morphology and physiology
Nicol Caplin (University of the West of England, UK)

14:40 Molecular and metabolic mechanisms of transgenerational effects of radionuclides in Daphnia
Frédéric Alonzo (IRSN, France)

14:55 Zebrafish exposure to environmentally relevant concentration of depleted uranium impairs progeny development at the molecular and histological levels
Olivier Armant (IRSN, France)

15:10 From DDREF to EDR - What the history of LNT indicates
Masako Bando (Osaka University, Japan)

14:00 - 15:30

ERPW SESSION 8:

Biomarkers and Cohorts Suitable for Exploring Low-Dose/Low-Dose-Rate Exposure Effects and Individual Susceptibility (Humans, Animals and Plants)

Ballroom V, VI

Co-Chairs: Almudena Real (CIEMAT, Spain), Michaela Kreuzer (BfS, Germany)

14:00 Cohorts for radiation research with focus on low-dose/low-dose-rate exposure effects and individual susceptibility
Olivier Laurent (IRSN, France)

14:30 Biomarkers for radiation research with a focus on human susceptibility
Catharine West (University of Manchester, UK)

15:00 Cognitive and cerebrovascular effects induced by low dose ionizing radiation 'CEREBRAD'
Rafi Benotmane (SCK•CEN, Belgium)

15:15 Development of quality assurance guidance and procedures for collecting a biobank of samples patients exposed to medical radiation
Päivi Roivainen (University of Eastern Finland)

15:30 - 16:00 COFFEE BREAK *Portland*

16:00 - 17:30
EURAMED & ICRP SESSION
(continuation):
Advanced Radiotherapy: Benefits and Radiation Protection due to Developments in Imaging, New Technologies, and Stratification
Ballroom I, II
Co-Chairs: Pierre Scalliet (former ICRP C3, Belgium), Virginia Tsapaki (EURAMED, Greece)

16:00 Proton Therapy Technology in the Clinic
Tom Depuydt (Katholische Universiteit Leuven, Leuven, Belgium)

16:30 Targeted Alpha Particle Therapy: Imaging, Dosimetry and Radiation Protection
Michael Lassmann (University Clinic of Wuerzburg, Germany)

17:00 Panel Discussion

16:00 - 17:00
ERPW SESSION 9:
Use of Observatory Sites for Integrated Long-Term Research Activities
Ballroom III, IV
Co-Chairs: Jacqueline Garnier-Laplace (ALLIANCE), Nathalie Vanhoudt (SCK•CEN, Belgium)

16:00 RED FIRE: Radioactive environment damaged by fire: a forest in recovery
Nicholas Beresford (CEH, UK)

16:15 Transfer and effects studies in the Chernobyl exclusion zone observatory site within the TREE project
David Copplestone (University of Stirling, UK)

16:30 Monitoring of contaminated forests from early post-accident phase to long term, an unavoidable tool to assess RNs cycling in forests
Frédéric Coppin (IRSN, France)

16:45 Research opportunities at the Belgian NORM observatory site
Nathalie Vanhoudt (SCK•CEN, Belgium)

17:00 - 18:00
ERPW SESSION 11:
Radioactive Iodine: Gaps and Knowledge Needed for Nuclear Crisis Integrated Management
Ballroom III, IV
Co-Chairs: Jöchen Tschiersch (HMGU, Germany), Olivier Masson (IRSN, France)

17:00 Radioactive Iodine: Reducing uncertainty of exposure assessment following nuclear emergencies
Jöchen Tschiersch (HMGU, Germany)

17:10 Reconstruction of accidental radioactive releases: Possible contributions of short- lived iodine isotopes to the source term and radiological consequences
Martin Sogalla (GRS, Germany)

17:20 Guidelines for development of monitoring strategies following a radioactive accident
James Marsh (PHE, UK)

17:30 Monte Carlo study of parameters influencing thyroid monitoring of I-131 after a nuclear accident
Jose M. Gomez-Ros (CIEMAT, Spain)

17:40 Using animal thyroids as ultra-sensitive biomonitors for environmental iodine-131
Georg Steinhauser (Leibniz University Hanover, Germany)

17:50 Chernobyl to Fukushima: what has changed with regard to radioactive iodine monitoring and measurement? What remains to do?
Olivier Masson (IRSN, France)

16:00 - 17:00
ERPW SESSION 10:
Harmonization of Practices Enabling Patient Dose Repositories
Ballroom V, VI
Co-Chairs: Guy Frija (University of Paris Descartes, France), Graciano Paulo (Coimbra Health School, Portugal)

16:00 Current regulatory and technological opportunities
Guy Frija (University of Paris Descartes, France)

16:15 Harmonization of practices in medical imaging: the way forward
Graciano Paulo (Coimbra Health School, Portugal)

16:30 Challenges in developing dose repository systems
John Damilakis (University of Crete, Crete)

16:45 Discussion

17:00 - 18:00
ERPW SESSION 12:
Dosimetry in Complex Fields
Ballroom V, VI
Co-Chairs: Jean-François Bottollier-Depois (IRSN, France), Marco Caresana (POLIMI, Italy)

17:00 Pulsed neutron fields: inter-comparison of various detectors
Marco Caresana (POLIMI, Italy)

17:20 The commissioning of new pulsed high-energy electron accelerator facility SwissFEL in Switzerland from a radiation protection point of view
Eike Hohmann (PSI, Switzerland)

17:40 Diagnostic reference levels of CT radiation dose in whole-body PET/CT: an Indian scenario
Sneha Mithun (Tata Memorial Hospital, India)

19:30 - 20:00 ICRP-ERPW COCKTAIL *Dome*

20:00 - 22:00 GALA DINNER *Dome*

THURSDAY OCTOBER 12

08:00 - 18:00 REGISTRATION *Front desk*

08:30 - 18:00 EXHIBITION AND POSTER SESSIONS *Portland*

09:00 - 10:30
NERIS & ICRP SESSION:
Post-Accident Recovery
Ballroom I, II
Co-Chairs: Jacques Lochard (ICRP Vice-Chair, France), Christophe Murith (NERIS, Switzerland)

09:00 Introductory Presentation: The New Mandate and Work of ICRP Committee 4 on Implementation of the Commission's Recommendations
Donald Cool (ICRP MC & C4 Chair / EPRI, USA)

09:15 Introductory Presentation: The Work Programme of NERIS in Post-Accident Recovery
Thierry Schneider (NERIS Chair, CEPN, France)

09:30 Medical and Health Surveillance in Post-Accident Recovery: Lessons Learned in Fukushima
Koichi Tanigawa (Fukushima Medical University, Japan)

10:00 The Role of Individual Dosimetry for Affected Residents in Post-Accident Recovery – From the Fukushima Experience
Wataru Naito (National Institute of Advanced Industrial Science and Technology, Japan)

09:00 - 10:30
ERPW SESSION 13:
Eye Lens Exposure and Monitoring
Ballroom III, IV, V, VI
Co-Chairs: Lara Struelens (SCK•CEN, Belgium), Isabelle Clairand (IRSN, France)

09:00 The European epidemiological study on radiation-induced lens opacities among interventional cardiologists: final results of the EURALOC project
Lara Struelens (SCK•CEN, Belgium)

09:20 Cataract avoidance with proton therapy in ocular melanomas: need for revised dose volume limits to the lens?
Juliette Thariat (Centre Antoine Lacassagne, France)

09:35 INSTRA - an integrated lifetime study in mice assessing lens opacities and other biological endpoints after exposure to low doses of ionizing radiation
Jöchen Graw (HMGU, Germany)

09:50 LDLensRad: Towards a full mechanistic understanding of low dose radiation induced cataracts
Elizabeth Ainsbury (PHE, UK)

10:05 Monitoring of radiation doses during coronary angiography and percutaneous transluminal coronary angioplasty procedures performed using flat panel detector
Gourav Kumar Jain (SMS Medical College, Hospital Department of Radiological Physics, India)

10:30 - 11:00 COFFEE BREAK *Portland*

11:00 - 12:30
NERIS & ICRP SESSION *(continuation)*:
Post-Accident Recovery
Ballroom I, II
Co-Chairs: Jacques Lochard (ICRP Vice-Chair, France), Christophe Murith (NERIS, Switzerland)

11:00 The Role of Experts in Post-Accident Recovery: Lessons Learnt from Chernobyl and Fukushima
Jean-Christophe Gariel (IRSN, France)

11:30 The Irish Approach to Post-Accident Preparedness
Ciara McMahon (Environmental Protection Agency, Ireland)

12:00 Panel Discussion

11:00 - 12:30
ERPW SESSION 14:
Individualized Approaches for Radiation Protection
Ballroom III, IV, V, VI
Co-Chairs: Hildegarde Vandenhove (SCK•CEN, Belgium), Elisabeth Ainsbury (DH-PHE, UK)

11:00 Challenges of individualized radiation protection: Identification of individual radiation sensitivity
Ulrike Kulka (BfS, Germany)

11:20 Individual radiation protection approaches in medical applications
Wolgang Doerr (University of Vienna, Austria)

11:40 Individual approaches in emergency scenarios
Andrzej Wojcik (University of Stockholm, Sweden)

12:00 Individual Sensitivity; Neither the issue or its solution should be thought of as radiation specific
Christopher Kalman (NHS Forth Valley, UK)

12:15 Reduced contrast volumes in small patients and more uniform inter-patient image quality with personalized contrast protocols in abdominal CT
Marie-Sofie Walgraeve (AZ Sint-Jan Brugge-Oostende, Belgium)

12:30 - 14:00 LUNCH *Cape Cod & Yacht Club & Providence*

Programme Schedule

13:30 - 15:00
ALLIANCE & ICRP SESSION:
Integrated Protection of People and the Environment
Ballroom I, II
Co-Chairs: Carl-Magnus Larsson (ICRP MC, Australia), Chris Burbidge (ALLIANCE, Ireland)

13:30 Introductory Presentation: Integration of Radiological Protection of the Environment into the System of Radiological Protection
Kathryn Higley (ICRP C4 / Oregon State University, USA)

13:45 Introductory Presentation: ALLIANCE Perspectives on Integration of Humans and the Environment into the System of Radiological Protection
Hildegarde Vandenhove (ALLIANCE /SCK•CEN, Belgium)

14:15 Integrated Protection of People and the Environment: A View from Japan
Kazuo Sakai (ICRP C1 / Tokyo Healthcare University, Japan)

14:30 Implementation of the Integrated Approach in Different Types of Exposure Scenarios
David Copplestone (ICRP C4 / Stirling University, UK)

14:00 - 15:00
MELODI AWARD CEREMONY
Ballroom III, IV, V, VI

14:00: Introduction and prize giving
Jacques Repussard, MELODI Chair

14:10: Presentation from the MELODI award winner
An Aerts (SCK•CEN, Belgium)

15:00 - 15:30 COFFEE BREAK *Portland*

15:30 - 17:00
ALLIANCE & ICRP SESSION *(continuation)*:
Integrated Protection of People and the Environment
Ballroom I, II
Co-Chairs: Carl-Magnus Larsson (ICRP MC, Australia), Chris Burbidge (ALLIANCE, Ireland)

15:30 Australia's Proactive Approach to Radiation Protection of the Environment: How Integrated is it with Radiation Protection of Humans?
Gillian Hirth (ICRP C4 / ARPANSA, Australia)

16:00 Transgenerational Effects and Radiosensitivity in Non-human Species
Christelle Adam-Guillermin (ALLIANCE/IRSN, France)

16:30 Panel Discussion

15:30 - 17:00
SUMMARY, ROUND TABLE WITH THE PLATFORMS CHAIRS
Ballroom III, IV, V, VI

15:30 Towards the development of the joint and individual roadmaps for radiation protection research
Nathalie Impens (SCK•CEN, Belgium) et al.

15:45 Feedback from the platforms chairs

16:30 Debate with the assembly

17:00 - 18:00 CLOSING CEREMONY *Ballroom I, II*

17:00 Concluding Remarks
Claire Cousins (ICRP)

17:10 Concluding Remarks
Jacques Repussard (ERPW)

17:20 Presentation
Cameron Jeffries (ARPS, Australia) to welcome participants to ICRP 2019 in Adelaide

17:35 Presentation
Ivica Prlic (IMI, Croatia) to welcome participants to ERPW 2018 in Rovinj

17:50 Concluding Remarks and Farewell
from the host Jean-Christophe Niel (IRSN)

Side Event Schedule

Closed Meetings

Day	Time	Meeting	Venue	Room
Monday October 9	13:00–15:00	CONCERT ExB/ESAB Meeting	*Newport Bay Club Hotel*	Ballroom V
Monday October 9	13:30–16:00	MELODI Scientific Committee	*Newport Bay Club Hotel*	Ballroom III
Monday October 9	15:00–17:00	CONCERT Management Board Meeting	*Newport Bay Club Hotel*	Ballroom VI
Monday October 9	16:30–19:30	MELODI Board & General Assembly Meetings	*Newport Bay Club Hotel*	Ballroom IV
Tuesday October 10	8:00–10:30	CONCERT Meeting on Research and Innovation supporting the Implementation of European Basic Safety Standards	*Newport Bay Club Hotel*	Cape May I, II
Tuesday October 10	8:00–18:00	CONCERT WP6 Meeting	*Newport Bay club Hotel*	Boston I, II
Tuesday October 10	10:00–13:00	LDLensRad	*Newport Bay Club Hotel*	Bridgeport II
Tuesday October 10	11:00–17:00	CONFIDENCE WP3 Meeting	*Newport Bay Club Hotel*	Clipper I, II
Wednesday October 11	9:00–12:30	CONFIDENCE WP4 Meeting	*Newport Bay Club Hotel*	Boston I, II
Wednesday October 11	9:00–12:30	NERIS Management Board	*Newport Bay Club Hotel*	Nantucket I, II, III
Wednesday October 11	14:00–17:30	NERIS R&D Committee	*Newport Bay Club Hotel*	Nantucket I, II, III
Wednesday October 11	18:00–20:00	CONCERT WP2-WP3 Meeting	*Newport Bay Club Hotel*	Cape May I, II
Thursday October 12	18:00–20:00	NEA International Radiological Protection School (IRPS) Management Board (MB)	*Newport Bay Club Hotel*	Boston I, II
Thursday October 12	18:00–20:00	MENA Meeting	*Newport Bay Club Hotel*	Cape May I, II
Friday October 13	9:00–17:00	Radiological Protection Working Group	*New York Hotel*	Grand Central I, II
Friday October 13	18:00–20:00	NEA International Radiological Protection School (IRPS) Management Board (MB)	*New York Hotel*	Suite 5244

EURADOS & ICRP Session: **Advances in Dose Coefficients**

Tuesday October 10 **14:00 - 17:00 Ballroom I, II**

The Mandate and Work of ICRP Committee 2 on Doses from Radiation Exposure

J.D. Harrison
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The practical implementation of the ICRP system of protection requires the availability of appropriate methodology and data. Over many years, ICRP Committee 2 has provided sets of dose coefficients to allow users to evaluate equivalent and effective doses for radiation exposures of workers and members of the public. The methodology being applied in the calculation of doses can be regarded as state-of-the-art, in terms of the biokinetic models used to describe the behaviour of inhaled and ingested radionuclides and the dosimetric models used to model radiation transport for external and internal exposures. This overview provides an outline of recent work and future plans, including publications on dose coefficients for adults, children and *in utero* exposures, with new dosimetric phantoms in each case. The Committee is also working with Committee 3 on dose coefficients for radiopharmaceuticals and leading a cross-Committee initiative to provide advice on the use of effective dose. The remit of the Committee has now been widened to include all data requirements for the assessment of doses to humans and non-human biota.

The Work Programme of EURADOS on Internal and External Dosimetry

W. Rühm
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Since the early 1980s, the European Radiation Dosimetry Group (EURADOS) has been maintaining a network of institutions interested in the dosimetry of ionizing radiation. As of 2017, this network includes more than 70 institutions (research centers, dosimetry services, university institutes, etc.), and the EURADOS database lists more than 500 scientists who contribute to the EURADOS mission, which is to promote research and technical development in dosimetry and its implementation into practice, and to contribute to harmonization of dosimetry in Europe and its conformance with international practices. The EURADOS working program is organized in eight Working Groups dealing with environmental, computational, internal, and retrospective dosimetry, dosimetry in medical imaging and radiotherapy, dosimetry in high-energy radiation fields, and harmonization of individual monitoring. Results are published as freely available EURADOS reports and in the peer-reviewed international scientific literature. Moreover, EURADOS organizes Winterschools and training courses on various aspects relevant for radiation dosimetry, and formulates the strategic research needs in dosimetry important for Europe. This paper gives an overview on the most important EURADOS activities. More details can be found at www.eurados.org.

Computational Phantoms, ICRP/ICRU and Further Developments

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Phantoms simulating the human body play a central role in radiation dosimetry. The first computational body phantoms have been based upon mathematical expressions describing idealized body organs. With the advent of more powerful computers in the 1980s, voxel phantoms have been developed. Being based on three-dimensional images of individuals, they offer a more realistic anatomy. Hence, the International Commission on Radiological Protection (ICRP)

decided to construct voxel phantoms being representative of the adult Reference Male and Reference Female for the update of organ dose coefficients. Further work on phantom development has focused on phantoms that combine the realism of patient-based voxel phantoms with the flexibility of mathematical phantoms, so-called boundary representation (BREP) phantoms. This phantom type has been chosen for the ICRP family of pediatric reference phantoms. Finally, due to the limited voxel resolution of the adult reference computational phantoms, smaller tissues, such as the eye lens, skin and micron-thick target tissues in respiratory and alimentary tract regions could not be properly segmented. In this context, ICRP Committee 2 initiated a research project with the goal of producing replica of the ICRP 110 phantoms in polygon mesh format, including all source and target regions, even those with micron resolution.

New Mesh-type Phantoms and their Dosimetry Applications Including Emergencies

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Mesh-type adult reference computational phantoms have been constructed in Committee 2 of the International Commission on Radiological Protection (ICRP) by converting the voxel-type *Publication 110* adult reference computational phantoms to a high-quality mesh format and adding those tissues that were below the image resolution of the voxel phantoms and could not therefore be represented in the *Publication 110* phantoms. The new mesh phantoms include all the necessary source and target tissues for effective dose calculations, including the 8–40-μm-thick target layers of the alimentary and respiratory tract organs, thereby obviating the need for supplemental stylised models (e.g. respiratory airways, alimentary tract organ walls and stem cell layers, lens of the eye and skin basal layer). To see the impact of the new mesh-type reference phantoms, dose coefficients for some selected external and internal exposures were calculated and then compared with the current reference values in *Publications 116* and *133* which were calculated by employing the *Publication 110* phantoms and the supplemental stylised models. The new mesh phantoms were also used to calculate dose coefficients for industrial radiography sources near the body, which can be used to roughly estimate organ and effective doses of the worker who is accidently exposed by an industrial radiography source; in these calculations, the mesh phantoms were deformed to reflect the obesity of the worker and also to evaluate the effect of the posture on dose coefficients.

ICRP Task Group 95: Internal Dose Coefficients

Francois Paquet[a], John Harrison[b]

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Internal doses are calculated using biokinetic and dosimetric models. These models describe the behaviour of the radionuclides after ingestion, inhalation and absorption to the blood, and the absorption of the energy resulting from their nuclear transformations. ICRP develops such models and applies them to provide dose coefficients and bioassays functions for the direct calculation of equivalent or effective dose from knowledge of intakes and/or measurements of activity in bioassay samples. During the past few years, ICRP has devoted a considerable amount of effort to the revision and improvement of models to make them more physiologically realistic representations of uptake and retention in organs and tissues and of excretion. Provision of new biokinetic models, dose coefficients, monitoring methods and bioassays data is the responsibility of Committee 2 and its Task Groups. Two reports in a series of documents replacing the *Publication 30* series and *Publications 54, 68* and *78* have been issued (OIR Part 1 and part 2). The first report describes the assessment of internal occupational exposure to radionuclides, biokinetic and dosimetric models, methods of individual and workplace monitoring, and general aspects of retrospective dose assessment. The following reports of the series (Parts 2 to 5) provide data on individual elements and their radioisotopes, including information on chemical forms encountered in the workplace; a list of principal radioisotopes and their physical half-lives and decay modes; the parameter values of the reference biokinetic model; and data on monitoring techniques for the radio-isotopes most commonly encountered in workplaces. For most of the elements, reviews of data on inhalation, ingestion and systemic biokinetics are also provided. Dosimetric data provided in the printed reports of the series include tables of committed effective dose per intake (Sv per Bq intake) for inhalation and ingestion, tables of committed effective dose per content (Sv per Bq measurement) for inhalation, and graphs of retention and excretion data per Bq intake for inhalation. These data are provided for all absorption types and for the most common isotope(s) of each element section. The electronic annex that accompanies this series of reports contains a comprehensive set of committed effective and equivalent dose coefficients, committed effective dose per content functions, and reference bioassay functions.

EURADOS Work on Internal Dosimetry

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EURADOS Working group 7 is a network on internal dosimetry which brings together researchers from more than 40 institutions in 21 countries. The work of the group is organised in task groups which focus on different aspects such as development and implementation of biokinetic models (e.g. DTPA decorporation therapy), individual monitoring and the dose assessment process, Monte Carlo simulations for internal dosimetry, uncertainties in internal dosimetry and internal microdosimetry. Several intercomparison exercises and training courses were organized. The IDEAS guidelines, which describe - based on ICRP biokinetic models and dose coefficients - a structured approach on assessment of internal doses from monitoring data are maintained and updated by the group. In addition, Technical Recommendations on internal dosimetry (in press) were elaborated on behalf of the European Commission, DG-ENER (TECHREC Project, 2014-2016, coordinated by EURADOS). Quality assurance of ICRP biokinetic models by calculations of retention and excretion functions for different scenarios was performed and feedback provided to ICRP. An uncertainty study of the recent cesium biokinetic model quantified the overall uncertainties and identified the sensitive parameters of the model. Currently a report with guidance on the application of ICRP biokinetic models and dose coefficients is drafted. These and other examples of the group's activities, which complement ICRP work, will be presented.

MELODI & ICRP Session: **Effects, Risks, and Detriment at Low Dose and Low Dose-Rate**

Wednesday October 11 **09:00 - 12:30** **Ballroom I, II**

The Mandate and Work of ICRP Committee 1 on Radiation Effects

30%的committee成員是放射生物專家，最新的 publicaiton 是ICRP115(2010)

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The International Commission on Radiological Protection (ICRP) was founded in 1928 at the second International Congress of Radiology in Stockholm, Sweden. Since then ICRP has published more than 130 reports including recommendations and guidance on various aspects of protection against ionizing radiation. The final objective is to protect humans against cancer and other diseases and effects associated with exposure to ionising radiation, and to also protect the environment, without unduly limiting the beneficial use of ionising radiation. As of the second half of 2017, four Committees are contributing to the overall mission of ICRP. Among those is ICRP Committee 1 on "Radiation Effects". This committee considers, among others, the risks and mechanisms of induction of cancer and heritable disease; discusses the risks, severity, and mechanisms of induction of tissue/organ damage and developmental defects; and reviews effects of ionizing radiation on non-human biota on a population level.

The present paper gives an overview on the recent activities of the committee, and in particular discusses the focus of the currently active C1 Task Groups.

Outcome of the European Initiative for Radiation Protection Research and Future Perspectives

新措施

J. Repussard
MELODI Chair

2009年，歐盟發佈了 “High Level and Expert Group”報告，指出低劑量輻射問題所帶來的科學挑戰，並且制定了歐盟層級相關政策擬定的proposal.

In 2009, the European Commission published the report of the "High Level and Expert Group", which had been mandated to consider the scientific challenges posed by the issues of low dose effects of ionizing radiation, and to formulate proposals for research policy evolution in this field, at European level. This report formulated a first draft of a strategic research agenda (SRA). It also suggested that the scientific communities concerned should organize a permanent dialogue on research strategies as well as priorities, and that the EURATOM research programs should encourage multidisciplinary initiatives and aim at strategic goals as defined in the SRA. This innovative approach was soon afterwards replicated in the fields of environmental issues and of emergency preparedness and post-accident management issues associated to ionizing radiation. Thus, European Platforms MELODI, ALLIANCE and NERIS were set up, and several EURATOM projects were successively funded to support this integrative process. EURADOS, a long established European scientific network on dosimetry also took on a formal status as a radiation protection research Platform. Lastly, in 2016, the main European medical professional associations announced the creation of the fifth Platform, named EURAMED. As these Platforms gathered credibility, and progressively included members from most of EU member states and beyond, EURATOM member states and the European commission pursued a policy of "integration" of radiation protection research by funding wide ranging projects covering all aspects of the field, and by introducing the rule of "co-funding" of this research by national programs, thus encouraging a programmatic convergence across Europe. The presentation will reflect on the results which have already been gained through this integration approach: comprehensive SRA's have been developed in all areas where radiation protection research is needed, their iteration year after year consolidating the consensus in the scientific community and with its stakeholders on the way forward; the scientific communities have learnt to organize open calls within wide ranging EURATOM projects. Research thus benefits from partners beyond the initial project consortium through procedures ensuring both openness and independence of judgment and confidentiality of the selection process; Platforms are also learning to work more closely together, for example to prepare a joint "roadmap" for future research in response to major societal expectations for radiation protection. Reflecting on the challenges that still lay ahead, the presentation will finally present the initiative that the five Platforms have jointly presented to the European Commission and EURATOM member states to further enhance radiation protection research in the next plurennial program, which will follow the current Horizon 2020 research Program.

目標

Evidence for Dose and Dose-rate Effects in Human and Animal Radiation Studies

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Abstract-Deterministic and stochastic effects associated with high dose ionising radiation (X-ray) exposure have been known for almost as long as ionising radiation itself. At lower doses radiation risks are primarily stochastic effects, in particular somatic effects (cancer) rather than the deterministic (tissue reaction) effects characteristic of higher-dose exposure. In contrast to deterministic (tissue reaction) effects, for stochastic effects scientific committees generally assume that at sufficiently low doses there is a positive linear component to the dose response, i.e. that there is no threshold; this does not preclude there being higher order (e.g. quadratic) powers of dose in the dose response that may be of importance at higher doses. It is on this basis that models linear (or linear-quadratic) in dose are often used to extrapolate from the experience of the Japanese atomic bomb survivor Life Span Study (LSS) cohort (typically exposed at a high dose-rate to moderate doses (average 0.1 Sv)) to estimate risks from low doses and low dose-rates. The so-called low dose extrapolation factor (LDEF), which consists of the ratio of the low dose slope (as derived via fitting a linear-quadratic model) to the slope of the straight line fitted to a specific dose range, has been used to derive the degree of over- (if LDEF > 1) or under-estimation (if LDEF <1) of low dose risk by linear extrapolation from effects at higher doses. Likewise, a dose rate extrapolation factor (DREF) can be defined, consisting of the ratio of the low dose slopes at high and low dose rate. Here we review a variety of human and animal data for cancer and non-cancer endpoints to assess evidence for curvature in the dose response (i.e. LDEF) and modifications of the dose response by dose rate (i.e. DREF). The most in-

formative human data on dose response curvature are from the LSS, which show strong evidence of curvature (i.e. LDEF > 1) for leukaemia and non-melanoma skin cancer, but only modest indications of curvature for other endpoints. There are indications in both the latest cancer mortality and cancer incidence datasets that curvature for other solid cancer endpoints is more pronounced in the recent time periods, and over the lower dose range, under 2 Sv. There is a body of data, some of it from the LSS, suggesting that the dose response for bone cancer (osteosarcoma) may be non-linear. The only useful information on modifying effects of dose rate (DREF) comes from comparing different populations, exposed at high and low dose rates, and as we review this may be problematic because of other variations (for example in underlying cancer risk) between these groups. There is a large body of animal data investigating effects of dose and dose rate. Among the most substantial is a corpus of murine and other experiments conducted at the JANUS reactor in Argonne National Laboratory from 1970 to 1992 to study the effect of acute and protracted radiation dose from gamma rays and fission neutron whole body exposure. A recently published reanalysis of the JANUS data for 36,735 mice (mostly *Mus musculus*, but some *Peromyscus leucopus*), 16,980 irradiated with neutrons, 13,647 irradiated with gamma rays, found that after gamma ray exposure there was significant non-linearity for all tumours, lymphoreticular, respiratory, connective tissue and gastrointestinal tumours, also all non-tumour, other non-tumour, non-malignant pulmonary and non-malignant renal disease ($p<0.001$). Associated with this the LDEF was significantly elevated for lymphoreticular tumours 1.159 (95%CI 1.059, 1.311), elevated also for a number of non-malignant endpoints, specifically all non-tumour diseases, 1.629 (95% CI 1.419, 1.987), non-malignant pulmonary disease, 1.696 (95% CI 1.175, 2.787) and other non-tumour diseases, 1.474 (95% CI 1.287, 1.851). However, for a rather larger group of malignant endpoints the LDEF was significantly less than 1, with central estimates generally ranging from 0.2-0.8, in particular for tumours of the respiratory system, vasculature, ovary, kidney/urinary bladder, mammary gland and testis. For neutron exposure most endpoints, malignant and non-malignant, showed downward curvature in the dose response, and for most endpoints this was statistically significant ($p<0.05$). Associated with this, the LDEF associated with neutron exposure was generally statistically significantly <1 for most malignant and non-malignant endpoints, with central estimates mostly in the range 0.1-1.1. There were statistically non-significant decreases of risk per unit dose at low gamma dose rates (5 mGy/hr) for most malignant endpoints, and non-significant increases in risk per unit dose at low gamma dose rates for most non-malignant endpoints. Associated with this, the DREF for many tumour sites was in the range 1.2–2.3, albeit not statistically significantly elevated from 1, while for most non-malignant endpoints the gamma DREF was less than 1. After neutron exposure there were non-significant indications of lower risk per unit dose at low dose rates (5 mGy/hr) for most malignant endpoints, and for all tumours ($p=0.001$), and respiratory tumours ($p=0.007$) this reduction was conventionally statistically significant; for most non-malignant outcomes risks per unit dose non-significantly increased at lower doserates. Associated with this, the neutron dose-rate extrapolation factor is less than 1 for most malignant and non-malignant endpoints, in many cases statistically significantly so, with central estimates mostly in the range 0.0–0.5.

Cancer Risk from Paediatric CT Scanning: Implications for Radiation Protection in Medicine

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Abstract-The use of computed tomography (CT) imaging is clearly beneficial for millions of patients. However, the potential adverse health effects, particularly cancer, of ionizing radiation exposure from CT early in life are an issue of growing concern in the radiological protection, medical and public health communities. Although efforts to quantify these effects have been conducted, the precision and accuracy of reported risks needs confirmation. EPI-CT, a European collaborative epidemiological study, was set-up to quantify risks from paediatric computerised tomography to optimise paediatric diagnostic protocol. The study, coordinated by IARC, was designed as a multinational cohort study of children and young adults who underwent CT scanning for long-term follow-up. It combined data from existing and extended cohorts in France, the United Kingdom (UK) and Germany, and from new cohorts assembled in Belgium, Denmark, the Netherlands, Norway, Spain and Sweden using a common protocol. A flexible dose reconstruction approach that can accommodate collection of data from historical sources (prior to 2000) and automatically extracted data from the Digital Imaging and Communications in Medicine (DICOM) headers of recorded images available in the Picture Archiving Communication System (PACS) was developed. Individual organ doses estimates for each child were derived from Monte-Carlo-based radiation transport calculations using hybrid phantoms of different sex and ages. To account for uncertainties due to missing input data, a simulation method which maintains correlations of doses for persons within subgroups with similar exposure attributes and simulates uncertain dose-model parameters values, was used. Simulation studies were conducted to evaluate the potential impact of a range of potential confounders (e.g. underlying medical conditions, socio-economic status, missing medical procedures performed outside of participating hospitals) on risk estimates were conducted based on data from some EPI-CT countries and/or reasonable scenarios. A total of 1,170,186 patients (before censorship) were enrolled in the national cohorts. Most patients (75%) had had only one CT

scan and 29% of all patients were younger than 5 years at the time of their first CT examination. The median duration of follow-up was 8.0 years for the entire cohort, though it varied across countries. Overall, the follow-up accounted for nearly 10 million person-years. The first estimates of risk of radiation related leukaemia will be presented and the impact of potential confounders on these estimates discussed. The study received partial funding from the EC 7th Framework Programme under grant agreement number 269912.

Cancer Risk following alpha emitter Exposure: a Risk Assessment of Task Group 64 of ICRP

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Radiation protection, based on quantitative estimates of cancer risk, relies mainly on results from Japanese A-bomb survivors exposed, during a few seconds, to external gamma radiation. ICRP decided to consider scientific publications of populations exposed to radon decay products, or to uranium or plutonium encountered during the nuclear cycle. Several experts are contributing to this synthesis: in dosimetric modelling focusing on major target organs/tissues, in epidemiology, statistics, in detriment calculation. Inhalation of radon gas and its decay products, observed in underground mining, but also in homes, is a long-term chronic exposure to alpha emitters. All studies of uranium miners presented an excess of lung cancer linked to the cumulative dose of radon decay products. Results from large case-control studies confirmed that at low domestic exposures (around 200 Bq per m^3), if lasted for at least 25 years, a clear excess of lung cancer was observed. ICRP *Publication 115* summarizes this information and suggests that exposure in homes should not exceed 300 Bq per m^3. Review of recently published results of workers exposed to plutonium, like Mayak workers (Russia) and Sellafield workers (UK), is close to completion; the results of a combined analysis related to lung cancer risk will be the basis of our final discussion. Scenarios of exposure to plutonium, to radon decay products or to external gamma exposure are proposed, in order to compare life-long lung cancer risk from two different alpha emitters and from external gamma exposure. For nuclear workers exposed to uranium, only a few studies are able to consider past individual exposure to uranium in its soluble or insoluble forms. More studies are needed before being able to quantify a specific cancer risk related to uranium.

Human Radiosensitivity and Prospects for Prediction

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Over the past few decades, there has been increasing recognition that the characterization of health effects following radiation exposure should extend beyond traditional assessment by epidemiologic methods to incorporate biological evaluation of differences in susceptibility between individuals. The idea of individual sensitivity to radiation in humans has long been supported by data from patients with certain rare hereditary conditions. However, these cancer susceptibility syndromes affect only a small proportion of the general population. More relevant to the majority of the population is the idea that some part of the genetic contribution defining radiation susceptibility may follow a polygenic model, which predicts elevated risk resulting from the inheritance of several low penetrance risk alleles. Here, we review current evidence from population-based studies of radiation-related risk in susceptible groups, including data from the candidate gene approach, genome-wide association studies, and tumor sequencing. While these studies are faced with several challenges (including the need for large sample sizes, high-quality exposure assessment and meaningful replication sets), results of recent studies indicate that the integrated assessment of radiation exposure and genetic and epigenetic alterations may lead to a more nuanced characterization of radiation-related risk.

EURAMED & ICRP Session:
Advanced Radiotherapy: Benefits and Radiation Protection due to Developments in Imaging, New Technologies, and Stratification

Wednesday October 11 **14:00 - 17:30** **Ballroom I, II**

The Mandate and Work of ICRP Committee 3 on Radiological Protection in Medicine

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Committee 3 is concerned with the protection of persons and unborn children when ionising radiation is used in medical diagnosis, therapy, and biomedical research, as well as protection in veterinary medicine. The Committee develops recommendations and guidance in these areas. The most recent documents published by the Commission that relate to radiological protection (RP) in medicine are "RP in Cone Beam Computed Tomography" *[Publication 129]*, "RP in Ion Beam Radiotherapy" *[Publication 127]*, "RP in Paediatric Diagnostic and Interventional Radiology" *[Publication 121]*, and "RP in Cardiology" *[Publication 120]*. A document in cooperation with Committee 2 entitled "Radiation dose to patients from radiopharmaceuticals: A compendium of current information related to frequently used substances" *[Publication 128]* has also been published. "Diagnostic Reference Levels in Medical Imaging" has been approved for publication by the Main Commission and is expected to be published before the end of 2017 *[Publication 135]*. It will provide specific advice for interventional radiology, digital imaging, CT, nuclear medicine, paediatrics and multimodality procedures. "Occupational RP in Interventional Procedures" was made available for public consultation in early 2017. The comments received are currently being considered. There is work in progress on several other topics. Other documents in preparation deal with guidance for occupational RP in brachytherapy, justification in medical imaging, RP in therapy with radiopharmaceuticals (an update to *Publication 128*), RP in medicine related to individual radiosusceptibility, and appropriate use of effective dose.

EURAMED's Vision on Medical Radiation Protection (Research)

C. Hoeschen[a] on behalf of the EURAMED Steering Committee
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While many other areas in radiation protection formed so called platforms in Europe, which provide strategic research agendas for their areas of interest, this did not happen for a long while in the area of application of ionising radiation which causes the largest man-made exposure at least in countries of the first world, i.e. medical exposure. Finally, in 2015 a European medical radiation protection strategic research agenda could be set-up and in 2016 a corresponding platform could be launched: EURAMED, the European Alliance for Medical Radiation Protection Research. In its SRA EURAMED defined its vision for medical radiation protection and the corresponding research needed. Five major topics were identified ranging from measurements of medical application related parameters like exposures and image quality to radiation biology aspects relevant for medical applications to individual optimisation strategies, to optimal use of techniques and harmonisation of practises finally to justification of the use of ionising radiation in medicine, all based on sufficient infrastructures for quality assurance. The ultimate goal is to individually lower radiation exposure and risk for patients and staff by interdisciplinary research between clinicians, physicists and engineers. Therefore it is essential that the results are translated into clinical practice.

Multimodal Imaging for Dose Planning and its Benefit: the Paradigm of Head & Neck Tumours

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The ultimate goal of any radiotherapy treatment is to eradicate the disease without inflicting damages to the normal tissues surrounding the tumours, which could be responsible for late treatment morbidity. To achieve this objective, the first step is to precisely select and delineate the target volumes to which a given dose will be prescribed. This step requires the use of multimodal images from clinical examination to anatomic and molecular images. Imaging examination will be used not only to delineate the boundaries of the tumour volume, but also to assess tumour heterogeneity and possibly to guide an heterogeneous dose prescription, i.e. the so-called "dose painting" approach. Last, re-imaging the patient during treatment to assess the variation of the tumour volume during radiotherapy may also be done in the framework of adaptive treatment. Over the last decade, a lot of information have been gathered on the use of multimodal imaging for dose planning and have identified both the promises and the technical difficulties. During the lecture, the speaker will review the state-of-the-art of multi imaging for the treatment using head and neck tumour as a paradigm. He will emphasise on what should be considered as routine practice and what should still be viewed as research questions.

The Need for, and Implementation of, Image Guidance in Radiation Therapy

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The introduction of image guidance in radiation therapy has revolutionized the delivery of cancer treatment. Modern imaging systems can supplement and often replace the historical practice of relying on external landmarks and laser alignment systems. Rather than depending on markings on the patient's skin, image-guided radiation therapy (IGRT) using techniques such as computed tomography (CT), cone-beam CT, MV on-board imaging (OBI), and kV OBI allows the patient to be positioned based on the internal anatomy. These advances in technology have enabled more accurate delivery of radiation doses to anatomically complex tumor volumes, while simultaneously sparing surrounding healthy tissues. While these imaging modalities provide excellent bony anatomy image quality, magnetic resonance imaging (MRI) surpasses them in soft tissue image contrast for better visualization and tracking of soft tissue tumors with no additional radiation dose to the patient. However, the introduction of MRI into a radiotherapy facility carries with it a number of complications including the influence of the magnetic field on the dose deposition, as well as the affects it can have on dosimetry systems. The development and introduction of these new IGRT techniques will be reviewed and the benefits and disadvantages of each will be described.

Proton Therapy Technology in the Clinic

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Proton therapy (PT) as a treatment modality is becoming more widely spread in the conventional radiation therapy practice. This process results in a trend toward embedding PT facilities in existing hospital environments. Also, technologically PT is currently going through an important evolution moving from passive scattering delivery techniques to active pencil beam scanning, and adopting image guidance techniques from conventional radiotherapy. An overview will be given of today's technological status of PT in clinical environments and its evolution toward becoming a mainstream technology in radiotherapy.

Targeted Alpha Particle Therapy: Imaging, Dosimetry and Radiation Protection

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Abstract-Alpha-particle emitters are highly potent therapeutical agents that are fundamentally novel in their mechanism and, most likely, overcome radiation resistance as the alpha particles emitted have a short-range (50 to 100 µm,) and a high linear energy transfer (LET). Alpha particles induce numerous DNA double-strand breaks along the respective tracks. Therefore, alpha emitters are becoming of increasing importance for the application in therapeutic nuclear medicine. The use of alpha emitters in a clinic environment requires extra measures with respect to imaging, dosimetry and radiation protection. This will be shown for the example of Ra-223-dichloride therapy. Ra-223-dichloride ("Xofigo®") is a radiopharmaceutical for the treatment of patients with castration-resistant prostate cancer, symptomatic bone metastases and no known visceral metastases. Radium is accumulating in bone when administered. Ra-223 decays to Pb-207, with four alpha emitters and two beta minus emitters present in the decay chain. The half-life of Ra-223 is 11.4 days, which is significantly longer than for any of the daughter radionuclides. Six administrations, four weeks apart, of 55 kBq/kg of body weight are foreseen for treatment. After an intravenous injection, Ra-223 leaves blood, is rapidly taken up in bone and bone metastases, and is mostly excreted via the intestinal tract.

Ra-223 can be imaged with a gamma camera. Several authors suggest that the imaging should be performed as a whole body scan at a low speed, with the camera equipped with either a medium- or a high energy collimator and with a 20% wide energy window centered on 82 keV. Dosimetry for alpha particles has to be performed on a small scale due to the short range of the alpha particles and a high local absorbed dose for determining the relative biological effectiveness (RBE) of a treatment. For obtaining this quantity, the differences in efficacy and toxicity to the conventional treatment using beta particles need to be assessed. Dosimetry based on compartment modelling shows that, after a series of six treatments for a 70 kg person with an administered activity of 55 kBq/kg Ra-223 each (overall: 23 MBq Ra-223) results in an absorbed alpha dose of approximately 17 Gy to the bone endosteum. The corresponding absorbed alpha dose to the red bone marrow is approximately 1.7 Gy. During the administration, special care must be taken to reassure that no spill is present on the skin of neither the patient nor staff and that there is no extravasation of the radiopharmaceutical. The treatment is normally performed on an outpatient basis; the patient should receive written information about the therapy and radiation protection.

NERIS & ICRP Session: **Post-Accident Recovery**

Thursday October 12 **09:00 - 12:30 Ballroom I, II**

The New Mandate and Work of ICRP Committee 4 on Implementation of the Commission's Recommendations

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Committee 4 of the ICRP is charged with the development of principles and recommendations on radiological protection of people and the environment in all exposure situations. For the term beginning in July 2017, the Committee has a total of 18 members from 13 countries. The program of work includes a wide range of activities in five major thematic areas. The first is the consolidation and preparation of reports elaborating application of the system of protection in existing exposure situations. Second is the continuation of work on emergency exposure situations, and the ICRP's updates to recommendations in light of the events at Fukushima Daichi. Third is examination of fundamentals of protection recommendations, including the ethical principles underlying the recommendations and application of those principles in practical decision-making. Fourth is the new area of integration of protection of the environment into the system of protection. Finally, the Committee continues work to prepare specific topical reports on subjects in which additional information is useful to understand and apply the Commission's recommendations in particular circumstances.

The Work Programme of NERIS in Post-Accident Recovery

T. Schneider

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NERIS is the European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery. Created in 2010, with 57 organisations from 28 different countries, the objectives of the platform is to: improve the effectiveness and coherency of current approaches to preparedness, identify further development needs, improve know-how and technical expertise, and establish a forum for dialogue and methodological development. The NERIS Strategic Research Agenda is now structured with three main challenges in: i) radiological impact assessments during all phases of nuclear and radiological events; ii) countermeasure and countermeasure strategies in emergency and recovery, Decision support and Disaster informatics; iii) setting-up a multi-faceted framework for preparedness for emergency response and recovery. The Fukushima accident has pointed out some key issues for further considerations in NERIS research activities. Among them, one can mention: the importance of transparency of the decision-making processes at the local, regional and national levels; the key role of the access to environmental monitoring at local, national and international levels; the importance to deal with uncertainties in assessment and management of the different phases of the accident; the use of modern social media in the exchange of information; the role of stakeholder involvement processes in both emergency and recovery situations; the considerations on societal, ethical and economic aspects; the reinforcement of Education & Training for various actors. The presentation will emphasize the main issues at stake for NERIS for post-accident management.

Medical and Health Surveillance in Post-Accident Recovery: lessons learned in Fukushima

K. Tanigawa

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In response to the Fukushima Daiichi Nuclear power plant accident, Fukushima Health Management Survey (FHMS) was implemented. The primary purpose of this survey was to monitor the long-term health of residents, promote their future well-being, and confirm whether long-term low-dose radiation exposure has health effects. The FHMS results indicated that radiation exposure doses of residents were very low and no discernible increased incidence of radiation-related health effects will be expected. However, psychological distress was found to be far greater in Fukushima than in other areas affected by the Tohoku earthquake and subsequent tsunami. Also, lifestyle-related health problems such as overweight, hypertension, diabetes mellitus, dyslipidemia, liver dysfunction increased among evacuees. Thyroid examination of asymptomatic individuals using ultrasound techniques has caused public concern and fear about the health effects of radiation. The Fukushima accident revealed that adverse effects on mental health due to the accident, health problems caused by long-term dislocation, and ethical issues related to mass-screening were much more significant than the direct effects of radiation. It is essential to balance the risks of radiation with other health effects after an accident, and to develop specific measures to mitigate the overall health risks (whole-health management).

The Role of Individual Dosimetry for Affected Residents in Post-Accident Recovery – From the Fukushima Experience

W. Naito, M. Uesaka

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The accident at Fukushima Daiichi Nuclear Power Plant on March 11, 2011, released radioactive material into the atmosphere and contaminated the land in Fukushima and several neighboring prefectures. In the rehabilitation stage, it is important to accurately understand or estimate realistic individual external doses so that individuals can make informed decisions based on their radiological protection to return to or live in the affected areas. The authors used personal dosimeter (D-shuttle) along with the Global Positioning System and Geographic Information System to understand realistic individual external doses and to relate individual external doses, ambient doses, and activity-patterns of individuals in the affected areas in Fukushima. More than 250 affected residents participated in our study. The results provide a valuable contribution to understanding realistic individual external doses, and the corresponding time-activity patterns and airborne monitoring air dose rate, which can be used for predicting future cumulative external doses following the return of residents to their homes in the evacuation order areas. In addition to the scientific evidence obtained from our study, the presentation will discuss and emphasise the meaning and role of individual external dose measurements for the affected residents in post-accident recovery based mainly upon the authors' experience in measuring, assessing and communicating individual external doses in the affected residents and areas in Fukushima.

The Role of Experts in Post-accidental Recovery: Lessons Learnt from Chernobyl and Fukushima

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Following a nuclear accident, a main dilemma for affected people is to decide to stay or to leave from the affected area, or, for those who have been evacuated, to return or not in the decontaminated zones. Populations who have to make such decisions have to take into consideration many parameters among which the radiological situation is only one among many others. Feedbacks from Chernobyl and Fukushima have demonstrated that the involvement and the empowerment of affected population is a manner to provide them elements to take informed decisions and, if they decide to be back on decontaminated areas, to minimize exposure by contributing to the development of a prudent attitude and vigilance towards exposure. However, involving stakeholders in the post-accident management raises the question of the role of experts (and public authorities) with regard to their support to the inhabitants who have to take decisions about their future. Based on several experiences in Chernobyl and Fukushima, this presentation will discuss about some principles that have to be taken into account by experts and public authorities about their role and position when dealing with stakeholders involvement in a post-accidental recovery process.

The Irish Approach to Post-accident Preparedness

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While Ireland has no nuclear facilities it has in place a National Emergency Plan for Nuclear Accidents. This plan was established, following the Chernobyl accident, for the national response to a nuclear accident abroad affecting Ireland. It has since been extended to also cover domestic radiological emergencies for which a national-level input is required to support the local response. This paper will look at the approach taken to developing and maintaining arrangements for a nuclear accident abroad. The use of hazard assessments to prioritise resource use and planned protective actions, and the specifics of Ireland's situation in terms of location, governance, economy and available resources have heavily influenced the preparedness arrangements. In particular, the importance of the ingestion pathway to projected doses, together with the significance of agricultural exports to the Irish economy, has had a key influence on the arrangements in place.

ALLIANCE & ICRP Session: **Integrated Protection of People and the Environment**

Thursday October 12 **13:30 - 17:00 Ballroom I, II**

Integration of Radiological Protection of the Environment into the System of Radiological Protection

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In 2005 the International Commission on Radiological Protection (ICRP) decided to create a new committee, Committee 5 (C5), to take charge of the Commission's work on environmental radiological protection. C5 was tasked with ensuring that the system for environmental radiological protection would be reconcilable with that for radiological protection of man, and with the approaches used for protection of the environment from other potential hazards. The task was completed over three consecutive terms resulting in inclusion of protection of the environment in the 2007 Recommendations; in *Publications 108* and *114* where the concept of Reference Animals and Plants (RAPs) and their corresponding data was described; in *Publication 124* on how to apply the system in planned, existing and emergency exposure situations, and in publications on improved dosimetry (approved as pending *Publication 136*) and ecologically relevant 'weighting factors' for different types of radiation (being finalised for public consultation). With the beginning of this new term, ICRP has moved to integrate its approach to protection of people and of the environment within the system of radiological protection by tasking aspects of an integrated system to each of the committees. Acknowledging that C5 had fulfilled its mission, ICRP in 2016 revised the mandates for the Committees effective of 1 July 2017 (the C3 mandate was also widened to include exposures incurred in veterinary practices). ICRP is moving towards the future, building on the previous successes, and will under these revised mandates approach radiological protection in a holistic manner (an integrated system) where appropriate consideration is given to the understanding of exposures and effects in the environment under different exposure situations and scenarios, and what protective actions might be warranted under such circumstances.

ALLIANCE Perspectives on Integration of Humans and the Environment into the System of Radiological Protection

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Risks posed by the presence of radionuclides in the environment require an efficient, balanced and adaptable assessment for protecting exposed humans and wildlife and managing the radiological risk associated. Approaches have been developed to assess or predict the transfer of radionuclides in the environment and their distribution/accumulation in relevant environmental compartments. Environmental concentrations of radionuclides serve as inputs to estimate the dose to man, fauna and flora. Dose estimates are then compared with the radiological protection criteria, such as those developed by the ICRP, for man and wildlife. This demonstrates the similarity in the approaches for impact assessment in humans and wildlife, suggesting the protection systems could easily be integrated; some elements are different, e.g. individuals are the focus of human assessments whereas for wildlife are populations. If human and environmental assessments are not consistent and complementary in terms of how they are conducted and the underlying databases (where appropriate), this may cause difficulties for operators and regulators and be difficult to communicate to wider stakeholders. Both in terms of the underlying philosophy and the application via appropriate tools, the ALLIANCE is convinced that integration in several ways and from several perspectives (e.g. chemical/radiological risks) is required for optimisation of impact assessment and decision support.

Integrated Protection of People and the Environment: A View from Japan

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Six and half years after the Fukushima Daiichi nuclear power plant accident, we still have an area of the existing exposure situation. One of the greatest concerns of people is the more elevated level of ionizing radiation than before, though there is no expected discernible health effect. After the accident, several "abnormalities" in environmental organisms were reported. It is still not clear whether many of these abnormalities were radiation-induced. It appears that the impact of the released radioactivity has not been sufficient to threaten the maintenance of biological diversity, the conservation of species, or the health and status of natural habitats, which are the focus in environmental protection. This highlights a difference between the protection of people and that of the environment; individuals for people and population for the environment. The system for environmental protection has been developed with an approach similar to that of the system developed for people. Reference Animals and Plants (RAPs) were introduced to connect exposure and doses in a way similar to that for "reference males and females". RAPs can also be used as a tool to associate the level of radiation (dose rate) with the biological effects on an organism. Here we identified another difference between the protection of people and that of the environment: an effect on people is measured in terms of dose and that on the environment is measured in terms of dose rate, i.e. protection criteria for people are expressed in term of doses (as dose limits, dose constraints, and reference levels), whereas those for the environment are expressed in terms of dose rates (as in the Derived Consideration Reference Levels). The Fukushima Daiichi nuclear power plant accident has created several challenges with respect to radiological protection systems. One challenge is regarding to the environmental protection. Considering the abovementioned differences will lead to an integrated system for the radiological protection of both people and the environment.

Implementation of the Integrated Approach in Different Types of Exposure Scenarios

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The ICRP recognises three different exposure situations (planned, existing and emergency). In all three situations, the release of radionuclides into the natural environment leads to exposures of non-human species, as well as having the potential for exposures of the public. This presentation will describe how the key principles of the ICRP system of radiological protection apply in each of these exposure situations. Current work in this area within Task Group 105 will be highlighted. For example, we are exploring how simplified numeric criteria may be used in planned exposure situations that are protective of both the public and non-human species. For existing exposure situations, we need to better understand the potential impacts on animals and plants especially when considering the remediation options that may be applied. Understanding both the radiological and non-radiological consequences may be important in making decisions. In emergency situations, understanding the potential impacts on non-human species may be important for communication, although in practice little may be done to mitigate their exposure. The TG is making use of examples of how exposure situations have been managed in the past to provide additional guidance and advice.

Australia's Proactive Approach to Radiation Protection of the Environment: How Integrated is it with Radiation Protection of Humans?

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Australia's regulatory framework has evolved over the past decade from the assumption that protection of people implies protection of the environment to the situation now where radiological impacts on non-human species (wildlife) are in their own right considered. In an Australian context, there was a recognised need for specific national guidance on protection of non-human species, for which the uranium mining industry provides the major backdrop. National guidance supported by ARPANSA publications in the Radiation Protection Series provides clear and consistent advice to operators and regulators on protection of non-human species, including advice on specific assessment methods and models and how these might be applied in an Australian context. These approaches and the supporting assessment tools provide a mechanism for industry to assess and demonstrate compliance with the environmental protection objectives of relevant legislation and to meet stakeholder expectations that radiological protection of the environment is taken into consideration in accordance with international best practice. Experiences from the past 5–10 years and examples of where the approach to radiation protection of the environment has been well-integrated, or presented some challenges will be discussed. Future challenges in addressing protection of the environment in existing exposure situations will also be discussed.

Transgenerational Effects and Radiosensitivity in Non-human Species

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The issue of potential long-term or hereditary effects for both humans and wildlife exposed to low doses of ionising radiation is a major concern. Animal and plant studies suggest that gamma irradiation can lead to observable effects in the F1 generation that are not attributable to inheritance of a rare stable DNA mutation. Several studies provide evidence of an increase of genomic instability detected in germ or somatic cells of F1 from exposed F0 organisms. This can lead to an induced radiosensitivity and phenotypic effects such as reproductive effects and teratogenesis. The ALLIANCE working group on effects of ionising radiation on wildlife brings together European researchers to work on this topic of transgenerational effects and radiosensitivity. The available studies show that differences of radiation sensitivity and mechanisms may be observed across species. In particular, studies are conducted to understand the possible role of epigenetic modifications such as DNA methylation, histone modifications or microRNAs in radiosensitivity as well as in adaptation effects. Understanding the main factors involved in these transgenerational effects across species will help to identify radiosensitive species that may require special attention in monitoring and protection. Finally, further investigation is required into the potential role of defined epigenetic effects in radiation-associated somatic diseases and heritable effects. Research using biological models in which the relative contribution of genetic and epigenetic processes can be elucidated is highly valuable.

ERPW Session 1: **Ethics in Radiation Protection**

Tuesday October 10 **14:00 - 15:30** **Ballroom III, IV, V, VI**

A broader set of ethical principles, or values, for radiation protection

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The four principles of biomedical ethics developed by Beauchamp and Childress – respect for autonomy, non-maleficence, beneficence, justice – are considered a point of departure for ethics in a number of different fields. We discuss here principles which go beyond the original set and which may be of particular relevance for radiation protection. In part, they have played a role in the choice of „core values" by ICRP's Task Group 94 on „Ethics of radiological protection" (to be published soon).

Human dignity – It could be argued that this is the basis of respect for autonomy and thus does not need to be invoked as an additional principle. We nevertheless prefer to do so, not least because dignity encompasses more than autonomy, forestalling discrimination for instance.

Precaution – This appears in the TG94 draft as „prudence", but we think an explicit reference to the precautionary principle may be of advantage: "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically."

Sustainability – Whereas the precautionary principle speaks mostly of action under uncertainty, consideration of future harms – and benefits – is better captured in the principle of sustainability.

Solidarity – There is a strong focus on the individual in the system of Beauchamp and Childress. The point can be made that this neglects the principle of solidarity which implies concern for the least advantaged or weakest in society, for instance children, or radiation sensitive people.

In addition to the original four principles and the extensions just outlined, more specific principles belonging to the area of behavioural and procedural ethics can be identified as important for radiological protection.

Honesty – Respect for autonomy and dignity require that we do not deceive people. Honesty, veracity, and truthfulness have therefore been suggested as guiding principles for the interaction between specialists and lay people exposed to radiation.

Accountability – That people should take responsibility for what they do is the basis of any legal system and it seems self-evident that the same should apply for those who expose others to radiation or decide about radiation exposure.

Empathy – For the physician, this would seem to be of prime importance in his or her relationship to the patient, but to feel with the other, to understand his or her worries, is relevant even in an area as scientific-technical as radiological protection.

Participation – There has been a lot of talk about stakeholder involvement over the last decades. To give people a say about their own health can be seen as an aspect of justice, as it would be unfair to pass over their concerns and aspirations without involving them.

We expect that these values will assist radiation protection personnel, radiographers and radiologists to deliver an ethically sound and humane form of practice.

Health surveillance and management of populations affected by a radiation accident – can ethics help?

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Public concerns about the potential health consequences of radiation exposures rank high after an accident. However, strategies for health surveillance of populations are often at odds with the actual needs of the affected populations and, if not carried out properly, can cause more harm than good. A striking example is thyroid screening carried out after Fukushima, which has been claimed to have exacerbated rather than alleviated anxiety in the participants and their families.

The EU SHAMISEN project has recently published a set of recommendations concerning health surveillance after a nuclear accident or other disasters. Experience suggested that an update of emergency preparedness in this area was needed for a number of reasons. These include the fact that existing recommendations had a technical focus, with less attention paid to social, ethical, psychological issues and that the information tended to be directed towards the decisions made by experts rather than for support of affected populations. Finally, there have been a number of changes in legal and ethical requirements for health surveillance and epidemiological studies (e.g., related to data protection) that need consideration. This paper presents the main conclusions and recommendations of the Shamisen project, with a particular focus on the ethical challenges related to health surveillance. The general recommendations address the need to do more good than harm, to respect dignity and to be sensitive to inequities from variability in the distribution of risk. An overarching theme that is reflected in many recommendations is the promotion of a health surveillance strategy that targets the overall well-being of populations, that addresses not only radiation effects, but also aims to identify and alleviate psychosocial impacts.

Drawing on values identified in the ICRP report on the ethical foundations of radiological protection (currently out for public consultation www.icrp.org), we identify ethically relevant issues linked to beneficence/non-maleficence, dignity, justice and prudence. We examine the ethical dilemmas that can arise for decision-makers, with the aim of improving understanding about the challenges of health surveillance and radiation risk management. We conclude that, in order for radiation protection to avoid causing more harm than good, there is a need to: 1) address the societal, ethical and psychological impacts of countermeasures; 2) be transparent about the objectives and aims of health surveillance; and 3) engage local populations in the design, implementation and follow-up of radiation risk assessment and management.

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Ethical framework for radiation protection in medicine: scenarios from diagnostic imaging

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The ethical framework for radiation protection in general has been under review in the international community for the last number of years. There is an emerging consensus on a core set of values, varyingly expressed, that appear to underwrite the system of radiation protection as we have inherited it. It is generally agreed that it is valuable to identify these values and allow them more explicitly influence the development of radiation protection into the future. The value system is recognisably close the value set for medical ethics proposed by Beauchamp and Childress in 1979, and which continues to be influential to the present day.

Radiation protection in medicine will benefit from the greater awareness of the ethical framework that underpins radiation protection in general. However, in addition to adhering to the principles of ICRP, radiation protection in medicine must also be consistent with medical ethics, and more explicitly with how the values involved are interpreted in the context of medical practice. For many practitioners, this will introduce a new perspective to their practices, as to date there has been an unspoken assumption that if medical procedures are conducted in accordance with ICRP principles, they fulfil all reasonable and legal expectations. To illustrate these considerations, a pragmatic set of values well adapted to medical use will be presented.

Many medical and radiation protection practitioners are not expert in ethics. To illustrate how the pragmatic value set, and the requirements of medical ethics might impact on practice, a series of scenarios from diagnostic imaging will be presented and analysed both from the perspective of the ethical values and the basic principles of ICRP. Interesting divergences occur. Some values have been used in a narrower sense in radiation protection than might be expected in medical ethics. In addition some values, such as precaution and honesty, may be side-lined inappropriately. These and related problems need much further discussion and the scenarios presented will help this.

Ethical considerations on the empowerment of people living in contaminated areas after a nuclear accident

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Fukushima as previously Chernobyl highlighted the importance of involving the population with the support of national and local authorities and experts to ensure the effectiveness and sustainability of protection actions in contaminated territories.

The empowerment of inhabitants is a key factor for the success of this involvement but is strongly questioned. That leads to important ethical questions such as: is this a strategy to let inhabitants alone to face the post-accident situation and for authorities and experts to be relieved of their responsibilities?

After the Chernobyl and Fukushima accidents, stakeholder involvement processes have been implemented in a few communities in Belarus, Norway and Japan. In this context, the availability of measurements devices for the inhabitants is crucial to allow them to assess their own radiological situation. Measurements allow to make radioactivity visible and to talk about it with others. Progressively people build their own reference and regain power to make choices and to retrieve control on their daily-life. One of the major lessons is the following: to protect efficiently the inhabitants living in contaminated areas, experts must work in cooperation with the local actors and develop together a co-expertise process.

But helping people to protect themselves does not mean that authorities and experts have no responsibilities and call for strong ethical principles; first of all is the refusal to take decision for the people about their future. To be helpful, scientists need to understand that, as necessary as radiation protection is, it is not the only issue inhabitants are facing and it cannot handle people's lives. Radiation protection experts must commit themselves to be at the service of individuals and the community and the issues they want to address.

It's the responsibility of authorities and experts to implement the conditions based on a governance involving the inhabitants allowing respect of freedom and justice. They have also the duty to address collective challenges such as ensuring equity between individuals and communities.

This paper will discuss the ethical considerations to be addressed by experts and authorities in the empowerment process for people living in contaminated areas after a nuclear accident.

A focus will be done on the questions raised on the current process of lifting the evacuation orders after the Fukushima accident.

Ethics, optimization, sustainability and radiation protection

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The ICRP recently completed a consultation exercise on a draft document setting out ethical foundations of the system of radiological protection (RP). This demonstrates that the system has, since its earliest development, taken account of both utilitarian and deontological attitudes, or, more simply, protection of individuals and the collective interests of society; balancing these appears to be key to effective decision-making. ICRP also has a Task Group reviewing the use of effective dose as a risk-related RP quantity. This quantity may be criticised, but it is otherwise unclear how ionising radiation exposure could be usefully discussed, let alone how an appropriate risk/benefit balance between the above perspectives could be determined. This determination will also inevitably involve value judgements beyond the robust, clear science of RP; i.e. where ethical consideration comes into play. For example, there continues to be impassioned debate about the linear, no-threshold (LNT) model of protection. The debate might best be resolved by dedicated, collaborative research addressing specific areas of disagreement, but in the interim consideration should be given to the consequences of this debate. Implementing the recommendations in ICRP 103 and the International Basic Safety Standards typically involves interpretation of optimisation within a national regulatory framework while accounting for local circumstances. Determining if dose limits/constraints or reference levels should apply is rarely straightforward, especially for older sites designed and initially operated inadequately by modern standards, but where there are also planned operations occurring concurrently with decommissioning and remediation work. The allowance of value judgements within optimisation drives the adoption of different strategies to address radiologically similar circumstances at different sites. Doses arising in planned exposure situations, and in the planned management of existing exposure situations, are almost exclusively in the low dose range, i.e. <100 mSv. Whatever interpretation one makes of low dose/dose rate effects, the risks of individual harm are very low. That, in itself, does not justify exposures, but effective communication of those low risks is vital for informed decision making, as supported by consultation with affected parties. Also, in many circumstances there are other risks present than the radiological. For example, chemical risks can dominate the post-disposal risks from low-level radioactive waste disposal. This paper explores the above issues and argues for a more constructive, unified presentation of radiation risks and uncertainties. The LNT debate is a diversion that weakens public confidence and hinders reasonable, intelligent application of optimisation. The ethical foundations of RP should be used to support a wider, sustainable view of optimisation with other professionals working in environmental and human health protection.

ERPW Session 2: Management of Emergency and Post-accident Situations: How to Optimise Population Evacuation Zones and Related Decision Making Processes?

Tuesday October 10 **16:00 - 17:35** **Ballroom III, IV, V, VI**

Evacuation in nuclear emergency: lessons from Fukushima Daiichi accident

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The accident of the Fukushima Daiichi nuclear power plant posed a serious challenge in evacuation planning and management. The arrangements on the basis of dispersion simulation did not work, and protective actions were decided based on plant conditions. The evacuation zone was gradually expanded up to 20 km away from the plant, while people within a radius of 20-30 km were ordered to shelter initially and were advised to voluntarily evacuate 10 days later. In addition, some areas beyond the 20 km zone were designated as "deliberate evacuation area", where residents were ordered to relocate from. Consequently more than 100,000 people were forced to evacuate/relocate. Although the evacuation and relocation helped to avert doses otherwise received, it came with a heavy price. A considerable number of elderly people, particularly those in hospitals and nursery homes, died during or after the evacuation. Those who were relocated have experienced disruption of living conditions, including loss of livelihood, family separation and community severance. Based on these bitter lessons, the Nuclear Regulation Authority conducted an in-depth review of emergency arrangements to formulate Nuclear Emergency Response Guidelines. The Guidelines place emphasis on the effective use of sheltering and set the operational criteria for implementing protective actions based on the observables and measurements. In case of emergency, residents in precautionary action zone (PAZ) are instructed to evacuate in a precautionary manner, while those in urgent protective action planning zone (UPZ) are supposed to shelter and evacuate depending on circumstances. Special arrangements are made for PAZ residents who require assistance, such as the inpatient, elderly, disabled, pregnant and infants. They are instructed to start evacuation or take refuge in a nearby radio-protective shelter at an earlier stage. Evacuation is the most straightforward protective action in an emergency, but the experience in Fukushima shows it has a disruptive or even destructive influence unless carefully managed. It is important to bear in mind that evacuation and relocation can be hazardous in many ways and optimizing the strategy requires consideration of a wide spectrum of potential consequences.

SHAMISEN recommendations and procedures for preparedness and health surveillance of populations affected by a radiation accident

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Background: The EU-OPERRA SHAMISEN project was conducted with the goal of producing a set of recommendations that would contribute to improve health surveillance and related communication with affected populations after nuclear accidents. Experience suggested that this was an area that had not been sufficiently addressed in current accident response planning in many European countries. It was also recognised that an update of emergency preparedness in this area was needed for a number of reasons, including the fact that existing recommendations had a technical focus, with less attention paid to social, ethical, psychological issues and that the information tended to be directed towards the decisions made by experts rather than for support of affected populations. Finally, there have been a number of changes in legal and ethical requirements for health surveillance and epidemiological studies (e.g., related to data protection) that need consideration.

Methods: The recommendations were developed by the SHAMISEN Consortium (partners from 19 institutions in 11 countries including Japan) and external experts from Belarus, Russia, Ukraine, Europe and the US based on reviews of guidelines in existence at the time of the Chernobyl and Fukushima accidents and of the actions which were taken, highlighting successes and limitations. The review includes case studies and lessons learnt from previous nuclear accidents. Advice from stakeholders at the local, national and international level was sought through meetings and a stakeholder forum.

Results: The recommendations (28 in total) aim at improving health and living conditions of potentially affected populations. They cover health surveillance, epidemiological studies, dose reconstruction, evacuation and training of health personnel and other actors involved in liaising with affected populations.

The recommendations are divided into general principles that apply across all phases of an accident, and three sets of specific recommendations for emergency and accident preparedness, the early and intermediate phase and the long-term recovery.

Recognising that a number of national and international organizations are working on strategies for nuclear emergency preparedness and health surveillance, as well as the considerable international expertise and experience that is available, the SHAMISEN recommendations are intended to be disseminated to radiation protection authorities, medical experts, affected populations and other scientific and non-expert audiences.

Conclusion: The SHAMISEN recommendations are available in the form of a booklet and on the web (radiation.isgobal.org\shamisen), both in a simplified format for the general public and in more details for other stakeholders. It is hoped that the SHAMISEN recommendations can contribute to the ongoing international

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To leave or not to leave? Insights from an empirical study on expected evacuation behaviour

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Understanding people's concerns, motivations, beliefs and value judgments underlying individual decision-making in an emergency situation, is crucial to improving the effectiveness of nuclear emergency response and recovery.

Within the European project CONFIDENCE (COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs), a dedicated work package addresses social, ethical and communication aspects of uncertainty management. Among others, it aims at identifying social uncertainties in emergency situations; highlighting ethical implications of uncertainty management; investigating lay person's decision-making behaviour; and developing improved communication of uncertainties, in particular for low radiation doses.

This contribution provides preliminary results from an empirical study on (self)evacuation behaviour in nuclear emergencies and related information needs. The study draws on social psychology models, including the Protective Action Decision Model (Lyndell and Perry, 2004, 2012), the Protection Motivation Theory (Rogers, 1983) and the Theory of Planned Behaviour (Ajzen, 1991). It aims at clarifying how people expect to react in an emergency; what is their perception of, and willingness to, follow official advice concerning evacuation from affected areas; and which factors influence expected behaviour. Potential explanatory factors investigated include descriptive norms, hazard and resource related attributes, self-efficacy aspects and trust in nuclear actors.

Data underlying the study originate from large scale opinion surveys in Belgium, Norway and Spain among different categories of lay publics.

The results will inform nuclear emergency preparedness and should contribute to the design of effective communication strategies.

Keywords: evacuation; expected behaviour; survey; CONFIDENCE

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Decision making in return to the evacuation zone based on the integrating cancer risk

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When a severe disaster occurred, prompt decision makings by the authority for protection of the public are no doubt important. This is actually difficult, however, because of the trade-off relationships among different-type detriments such as health risks, costs, inconvenience, stress, etc., as highlighted in the Fukushima Daiichi accident. For taking smoothly the most appropriate actions, it is desirable to prepare various risk projections in advance according to typical scenarios.

In the post-accident situation at the area near the Fukushima Daiichi nuclear power station, controversial discussions have been going on between the authorities and the residents about "how safe is safe". While the governmental officials explained that 20 mSv in the initial year was acceptable for living, many of the residents have shown strong concerns for accepting it; one of the major reasons is a higher health risk of radiation exposure to children than to adults.

For avoiding this controversy, the author is presenting procedures of cancer risk projections for female children, i.e., the most radiologically sensitive group, at the areas with different levels of radiocaesium depositions on to the ground. As results, the integrating lifetime attributable risk of cancer mortality of female children up to 18 years old due to external gamma-ray exposure from radiocaesium in soil was estimated to be 0.9 % for ^{134}Cs and 2.4 % for ^{137}Cs in case of the initial annual dose of 20 mGy y^{-1}. In case that the initial dose was 5 mGy y^{-1}, the integrating cancer risk would be 0.2 % and 0.6 % for ^{134}Cs and ^{137}Cs, respectively.

These results indicate that accurate information on the composition and behavior of major radionuclides released to the environment in addition to precise dose monitoring data and dose-to-risk conversion coefficients are critically important for proper decision makings on protective actions for the public. It is desirable to prepare comprehensive datasets for smooth risk projections before another unexpected incidence occurs in future.

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Role of citizen measurements in radiation protection, emergency preparedness and response - its pros and cons

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An involvement of stakeholders and general public plays one of key roles in the process of effective solving problems in emergency preparedness, response and remediation on affected territories. To accomplish these tasks, it is necessary to gain the participants´ confidence to information on radiation situation provided by the authorities.

The experiences gained from the Chernobyl and Fukushima NPP accidents have shown that especially in case of severe accident with significant consequences on large inhabited areas a lack of public confidence to officials was caused mostly by poor communication between the official authorities, the public and the stakeholders or by restricted access to the information for them. These may result into extremely negative impacts on the public and stakeholders´ understanding of actual situation, its possible risks, on their acceptance of necessary protective measures and participation in remediation of affected areas.

An implementation of citizen radiation monitoring performed on a voluntary basis in this field may improve such a confidence. Making sure, the official results are compatible with the citizens self-measured ones, the public probably gains more confidence to them.

In the Czech Republic the implementation of such an approach is investigated in the framework of security research founded by the Czech Ministry of the Interior. Especially RAMESIS Research Project solved by SURO is aimed at creating tools for supporting and establishment of a citizen monitoring network based both on the network of fixed monitoring points equipped with newly developed simple and cheap fixed monitoring stations and on mobile monitoring performed using the Safecast "bGeigie nano" portable devices. The next project task is preparation of methods and tools to utilize these citizen networks results by the National Radiation Monitoring Network operated by the state. This can also improve efficiency of obtaining information needful for a fast and effective evaluation of the radiation situation in case of accident.

Analysis of possible capabilities of such citizen's networks shows that monitoring of all roads on the whole CR territory may be carried out for one day using only about 300 mobile devices. In this manner both areas with higher levels, which need professional contamination monitoring, may be identified, and areas with no significant increase of dose can be confirmed.

Our analysis shows that the citizens monitoring networks can provide useful information not only for evaluation of radiation situation during the first phase of a radiation accident, but also for the phase of territory remediation to assess a future development of radiation situation and to evaluate an effectiveness of remedial measures.

The paper shows selected results of selected security research projects aimed at this field, supported by the Czech Ministry of Interior (RAMESIS, ID: VI20152019028) and by the Technology Agency of CR (CK RANUS, ID: TE01020445)

ERPW Session 3:
Why is Radioecology an Essential Science when Analyzing Human Population Exposure?

Wednesday October 11 **09:00 - 10:30** **Ballroom III, IV**

Artificial neural network for prediction of Sr-90 soil to plant transfer factor

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The transfer of radionuclides from soil to plants determines the extent of food contamination and, consequently, the risk of radioactive exposure of the. Dose assessment is one of the criteria which determine radiation protection measures for contaminated agricultural areas; other criteria include social and economics features of affected areas. The soil-plant transfer factor (TF) is an essential parameter for dose calculation as it determines the transfer to crops and also animal forages and hence the dose to human consumers. The TF is estimated as the dry matter activity concentration in the edible part of plants relative to that in soil. Different soil types, plant species and varieties, and agricultural practices, result in a large variation in TF values for the same element and consequently, the use of generic FT values may underestimate or overestimate risk. For a given soil type, the knowledge of a ^{90}Sr TF value for a given crop, allows the generation of TF values for other crops, using a conversion factor. Over the last 30 years, only 82 papers involving the behavior of ^{90}Sr in the soil-plant system were published in indexed journals, and the majority of these were published in the 90s, largely due to the Chernobyl accident. Over the last five years, 17 articles were published on ^{90}Sr TF perhaps demonstrating the topicality and requirement for knowledge. It is relatively well knowing that the main parameters that influence the TF for ^{90}Sr are: soil particle size, organic matter content (OM), pH, exchangeable potassium (K) and calcium (Ca). However, an evaluating of TF data through multiple regressive analysis, reported that the cation exchange capacity (CEC), soil organic matter (SOM) content, pH, the time of contamination and concentration of ^{90}Sr in the soil are variables able to explain something around 80% of the variation in TFs. In this work, the computational method of artificial neural networks (ANN) was applied to evaluate the possibility to predict TF for ^{90}Sr in leafy vegetables and cereals as a function of soil parameters. The method used values of ^{90}Sr TF from national and international literature in which pedological information were available. After the ANN training, a high correlation was obtained (r = 0.81; n = 69) between the ^{90}Sr TF literature values and those predicted by the artificial neural network, confirming that selected soil parameters (SOM, exchangeable Ca and K content and pH) could explains most of observed TF values for cereal grains. An even better neural network performance was obtained for leafy crops (r=0.95; n=41).

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Comparison of tritium environmental measurement results with air dispersion modeling using lagrangian particle dispersion model

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The aim was to obtain first results of airborne tritium in the surroundings of Krško Nuclear Power Plant (NPP), Slovenia, and based on those measurement results to compare them with the existing atmospheric dispersion modeling including the dose estimate for the representative person. The Pressurized Water Reactor (PWR) is a heart of Krško NPP which is placed in south-eastern part of Republic of Slovenia.

During normal operation of the NPP, the activity concentrations of released radionuclides in the environment are usually below the detection limits. Therefore, the influence on the population and the environment can be evaluated only indirectly from the data on the released liquid and atmospheric effluents. The exposure of the population can be estimated using models which describe the dispersion of radionuclides in the environment via various exposure pathways. To evaluate the atmospheric releases from Krško NPP, a Numerical Lagrangian Particle Dispersion Model (LPDM) SPRAY in an association with 3D meteorology is being used. The model takes into account complex situations, especially important for the Krško region: strong meteorological inhomogeneities and non-stationary, low wind calm conditions. The model was tested and validated in various and complex scenarios, however it is highly demanding to carry out the comparison of measured and calculated data. To challenge this task the tritium measurements in the environment were used.

A new method for determining the activity concentration of tritium in the atmosphere has been developed. The sampling time in the developed method is rather short (1 hour), which is an undoubted advantage in comparison with the already existing methods for determining the concentration of tritium in the atmosphere. To prepare samples for measurements, the lyophilization method was used. To measure the activity concentration of tritium in the sample, the liquid scintillation counting method was used. It has been shown that when using 100-120 grams of silica gel (as an air absorber) and with a sampling time of 1-1.25 hours, a sufficient amount of condensate (more than 8 grams) can be obtained to measure tritium activity concentration.

Acknowledgements The authors would like to give a sincere thanks to Mr. Drago Brodnik who gave significant contribution to arrange and to set up the experimental facilities for tritium collection.

Dynamic modeling of radionuclide transfer between water and biota to estimate seafood contamination

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In the marine environment, modeling radionuclide transfer to biota usually assumes that a steady state occurs between water and biological compartments. For each element, a mean value of the ratio between the concentrations in the biological compartment and the water in steady state (Concentration Factor CF) has been derived from observations. Recommended values for major biological groups can be obtained from IAEA Reports (TRS#422; TRS#479). However, in the case of rapid changes in radionuclide concentration in water (near the source of input or in an accidental situation for example), the assumption of a steady state is not met. Indeed, radionuclide transfer between the water and living organisms takes time and sharp changes in the water are smoothed out in biota. In terms of radioprotection, whether it involves human seafood or environment protection, assuming a steady state where it does not occur results in significant assessment bias. Examples of differences in assessment results are presented to illustrate this bias. To improve modeling of radionuclide transfer to biota, it is therefore recommended to take into account the kinetics of the transfer and this can be achieved by implementing a second parameter, the biological half-life (tb1/2). Though numerous values of tb1/2 have been reported in the literature, no recommendation is actually available and selecting a suitable value is challenging. A possible way to estimate tb1/2 is to derive its value from time series concentration measurements in the natural environment. The approach requires that concentration data are available both in the water and the biota. In the English Channel, a hydrodynamic model has been finely tuned and extensively validated and concentrations in seawater can be calculated reliably anywhere as a function of time, provided discharges data are known. Therefore, wherever time series concentrations are available in any biota in the English Channel, the hydrodynamic model can calculate the corresponding data in the water. We collated time series of radionuclide concentration measurements available around the North of the Cotentin Peninsula (English Channel) over the 80's and 90's decades. We used the hydrodynamic model to calculate the match data in the water on the basis of inputs from the major local source of liquid radioactive discharge in the English Channel, i.e. the nuclear reprocessing plant of AREVA NC La Hague. We derived tb1/2 values from these datasets and produced paired values of dynamic transfer parameters (CF, tb1/2) for several radionuclides to model radionuclide transfer between seawater and biota groups. We also analyzed statistically the residual between the observed and calculated values in biota to characterize the reliability of this modeling. We aim at producing recommendations for dynamic transfer parameters to be used in the English Channel together with an assessment of the confidence in the reliability of the model predictions.

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Sensitivity of the modelling of the transfers of radionuclides in freshwaters to the liquid-solid exchanges

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The radiological quality of freshwater environments submitted to radioactive pollutions involve numerous mechanisms of radionuclides transfers and the radiological impact to human populations and non-human biota depends on several pathways involving the aquatic food chain and the use of water resources. The parameters describing these mechanisms often present a high variability and it is therefore important to identify which of them are the main responsible for the uncertainty of the models. Among the influential mechanisms, the solid-liquid fractionation of radionuclides has a major influence on their transit times and their bioavailability and, consequently, on levels of exposure of humans and wildlife to radioactivity. In practice, the empirical Kd approach remains the simplest and most frequently used to model this fractionation in spite of strong uncertainties resulting from the large variability of Kd which can cover several orders of magnitude. To reduce this variability, the international community (e.g. see IAEA programs EMRAS, MODARIA…) compiles Kd values to update and refine statistical distributions of Kd as a function of radionuclides, environmental components (suspended and deposited sediments) and exchange conditions (adsorption, desorption and in situ). In order to optimize these efforts, it is useful to analyze the sensitivity of freshwater radionuclide transfer models to this fractionation in view to assess the maximum levels of Kd variability from which model uncertainties become poorly sensitive to the solid-liquid fractionation of radionuclides. In this context, this presentation concerns the assessment and analysis of the contribution of Kd variability to the uncertainties of the simplified models of transfers of radionuclides in freshwaters. After an overview of the mechanisms contributing to these transfers, the simplified models and the method of calculating their uncertainties are presented. The results allow identifying different hydro-sedimentary conditions for which the variability of solid-liquid fractionation contributes more or less to the total uncertainty of the models. In assessing human or wildlife exposure to contaminated freshwaters, these results allow modulating the importance of solid-liquid fractionation of radionuclides as a function of hydro-sedimentary conditions. They also allow determining the maximum ranges of variability of the Kd below which the uncertainties of the models are low sensitive to the variability of the solid-liquid exchanges of radionuclides.

Human food chain modelling within the CONFIDENCE project

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The EURATOM funded CONFIDENCE (COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs) project is considering various aspects of emergency management with the aim to reduce and cope with uncertainty. Here we consider activities within CONFIDENCE to improve the capabilities of human foodchain models, including to better characterise, and where possible, reduce uncertainties.

There are considerable uncertainties associated with the radioecological simulation models used to predict the transfer of radionuclides along the terrestrial foodchain. Initially after an accidental release the factors determining the contamination of foodstuffs will largely be defined by vegetation interception and the time of year. During the transition phase, factors controlling the uptake of radionuclides to vegetation from soil will become more important and these will dominate in the long-term rehabilitation phase. However, predictions made using radioecological models will be used in the early part of the transition phase to make longer-term decisions, e.g. with regard to remediation strategies. Therefore, models must be sufficiently robust and fit for purpose.

In CONFIDENCE, we are considering the following aspects of the modelling of radionuclides within the human foodchain:

Reducing parameter uncertainty

To improve underlying radioecological models we are: i) characterising and analysing the underlying PDFs associated with transfer parameters to better enable uncertainty/sensitivity analyses; ii) conducting targeted field ^{131}I tracer studies on the plant-animal-milk pathway (considering climate and stable I status); iii) consolidating ^{90}Sr data from Chernobyl and surrounding areas; iv) characterising the behaviour of Cs and Sr in Mediterranean production systems (including seasonality and key regional produce); v) considering how recent knowledge would change/improve terrestrial food and dose predictions; vi) learning from post-Fukushima (e.g. what radionuclides and/or pathways presented 'surprises' or were predictions difficult for); vii) evaluating the application of extrapolation approaches (ionomics, allometry, stable elements) to improve predictive ability for poorly studied radionuclides.

Process based models to reduce model uncertainties

We are: i) investigating the application of process based models; ii) investigating the applicability of process based Cs models to European soil types; iii) investigating process based model options for Sr; iv) assessing the added value of using process based models in comparison to empirical ones; v) investigating how process based models can be incorporated into Decision Support Systems.

Including 'hot particles' in radioecological models

We are: i) identifying which food products and radionuclides are sensitive to hot particles being deposited; ii) incorporating hot particles into models to improve predictions.

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Application of the system of radiological protection of the environment in the IAEA safety standards – a position paper

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From the mid-1990s onwards the notion that the system of radiological protection developed for humans also provides adequate protection to the environment has been increasingly challenged by the international radiation protection community. Since then considerable effort has been dedicated at both national and international level to gather scientific evidence of the radiation risks to non-human biota and to develop an appropriate system of radiological protection for the environment, consistent and complementary to that for humans.

Over the last 20 years the IAEA, together with other international organisations, such as ICRP, UNSCEAR and IUR, has played an active role in the development of principles, assessment methodologies and a regulatory framework which takes explicit consideration of protection of the environment. Protection of the environment was explicitly addressed for the first time by the IAEA in its Fundamental Safety Principles, published in 2006, whilst key considerations for protection of the environment were included in the IAEA Basic Safety Standards, published in 2014.

In 2013 the IAEA Coordination Group on Protection of the environment concluded that "the approach to address radiological protection of the environment developed by the ICRP … is conceptually and scientifically sound enough to be adopted into international radiation safety guidance for those circumstances when a more explicit consideration of the protection of non-human biota is considered necessary".

This paper describes how the current the system of radiological protection for the environment as recommended by ICRP has gained consensus within the radiation protection community and how it has been successfully incorporated into a number of recent IAEA Safety Standards. The paper also provides an overview of the current activities which are being carried out by the IAEA in this area (i.e. the MODARIA programme and the support provided to the London Convention on the application of radiological exclusion and exemption principles to sea disposal, and to the OSPAR convention on the derivation of environmental assessment criteria).

This paper also discusses the future direction that work on protection of the environment should take, looking at both the research needs to further investigate the possible radiation risks to non-human biota and the requirements for the application of the system to the environmental international safety framework. The paper will address the relationship between research, the ICRP approach to address radiological protection of the environment and the regulatory requirements at national and international levels and the paper will discuss the suitability and applicability of current assessment methodologies and the need and advisable pace for their refinement.

ERPW Session 4: Benefit vs Risk in Diagnostic and Interventional Radiology, Nuclear Medicine, and Radiotherapy

Wednesday October 11 **09:00 - 10:30** **Ballroom V, VI**

Benefit vs. risk in diagnostic and interventional radiology

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ICRP defines justification as the process of determining whether a planned activity involving radiation is, overall, beneficial, i.e. whether the benefits to individuals and to society from introducing or continuing the activity outweigh the harm (including radiation detriment) resulting from the activity, or in short words "do more good than harm". This definition is applicable to any types of exposure including medicine. Risk calculations and factors for exposures are available from ICRP 103 and BEIR VII and are applicable to healthy persons of different age and gender of a general population. When radiation is applied in medical procedures the process of justification involves additional patient related aspects like age, general condition, diseases, reduced life expectancy, the distribution of exposures among different patient groups and the risk of alternative procedures. The contribution of all these non-radiation related factors will be analysed. In summary the risk factors of ICRP 103 or BEIR VII overestimate the radiation related risk of patients as long as no screening of healthy individuals is involved.

Benefit vs. risk in nuclear medicine

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The use of ionizing radiation in medicine should always be appropriately justified, thereby balancing the corresponding risks and benefits for the individual patient. Furthermore, a risk-benefit analysis is part of the optimization process. In fact, patient dose will directly affect image quality and thereby the diagnostic accuracy. In this framework of justification and optimization, both clinicians and medical physicists should work closely together.

In diagnostic nuclear medicine, literature predominantly focuses on stochastic risks such as cancer induction. Even though radiogenic cancer risk models are available, the calculation of the cancer risk from a diagnostic procedure is prone to very large uncertainties. On the other hand, the quantification of the patient benefit is not straightforward as well. The most practical approach is the estimation of the lives lost by not performing the procedure or by performing an alternative, more invasive procedure. When justification is done properly, the benefits of the use of diagnostic radiopharmaceuticals far outweigh any potential risks.

Apart from diagnostic procedures, a large amount of radionuclide therapies are available as well. In these therapeutic settings, large amounts of activity are used and thus deterministic effects are most critical. First, the target should receive a sufficiently high radiation dose, whereas doses to organs-at-risk should be minimized in order to avoid side-effects of the treatment. The latter balance can be optimized by means of the individualized calculation of the administered activity. Failing to do so may result in significant under treatment of the patient or introduction of severe or even lethal side-effects of the therapy.

Benefit vs. risk of radiotherapy

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Ionizing radiation dose prescriptions given in radiotherapy balance benefits versus risks to maximise cancer patient survival and mimize side-effects. Thus, the goal of treatment planning is to optimise beam delivery to maximise tumour control probability (TCP) and minimize normal tissue complication probability (NTCP). However, radiotherapy schedules treat populations rather than individuals and for each patient are based on meeting physics dose and volume constraints with the constraints established from patient cohorts. Treatment planning evaluation and optimization should be more effective if it is biologically rather than dose/volume based, some centres are now starting to optimize TCP versus NTCP on an individual patient basis.

Psychosocial analysis of radiation protection in the medical field: perspective for IRSN

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Background: Exposure to ionizing radiation (IR) in the medical field represents the largest intentional exposure. In addition, this type of exposure is growing with the rise of imaging and collective dose (IRSN-PRP-HOM report No. 2014-6). Through the various types of imaging, and particularly through mammography, the general population is exposed to IR. However, issues related to exposure remain quite unknown from general public: information on this risks incurred is not consensual. IRSN is developing a dedicated website "Radiation protection in Questions" for a clarification of issues and a better information, communication and training of the population.

However, communicating around the IR risks and IR benefits to the general public involve beliefs, representations and fears about "nuclear" idea. In order to facilitate understanding and guide the behaviors in the direction of prevention promoted by the IRSN, it is necessary to study through a psychosocial study the social representations of "nuclear" in the medical field. We will use the example of breast cancer screening to conduct our study. Its framework is based on the theory of social representations, which is particularly relevant for health behavior and prevention studying.

Methods: Several data collection are to be set up.

- An analysis of the public, professional and institutional media discourse will be conducted. This study aims to better understand the information content at differents level: public, professional, patients, institutions, learning societies.
- A quantitative data collection from women involved in organized breast cancer screening and from women concerned about individual screening. Our goal is to investigate the representations of the screening and the particular use of ionizing radiation in the screening from the women perspective.
- A collection of data from the professionals concerned: gynecologists and general practitioners who prescribe or invite women to perform a mammogram; Radiologists and manipulators because they are directly concerned by this act. This collection of information and information circulates between them and the women who consult them.

Perspectives: Following an overall analysis of these different data collections, we will be able to highlight the core elements of the representations we investigate. Data analysis will provide the IRSN with relevant recommendations.

Risk projection in pediatric computed tomography – methods, limits and value for clinical practice

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Direct estimation of radiation-related risks of diagnostic imaging, including computed tomography (CT), is challenging due to low relative risks, long latency times and multifactorial outcomes. It requires including very large populations of patients for whom accurate exposure information is available and decades of follow-up after CT exams are achievable. The variety of pre-existing medical conditions at the time of the examination, and possibly environmental and lifestyle factors, must also be considered when investigating future health outcomes.

Methods have been developed to predict radiation-related risks using dose-response models derived from cohorts of the survivors of the Hiroshima and Nagasaki atomic bombings and patients receiving high x-ray doses for benign conditions, which now benefit of an almost lifetime follow-up. The derived site-specific risk models provided excess risk per dose unit depending on gender, age at exposure and time since exposure and assuming a linear no-threshold relationship. We adapted the methodological framework proposed by the BEIR VII and UNSCEAR scientific committees to project future cancer risks subsequent to childhood CT scans. Estimation of individual radiation doses was based on surveys of hospital practices in France (2004–2009) and United Kingdom (2000–2008).

The magnitude of projected risks of developing a cancer (all tumor sites combined) was 0.1–1 per 1000 head scans and 1–5 per 1000 non-head scans overall. Relative to baseline cancer risks, each single scan during childhood would lead to one excess case per 1000 spontaneous cancers on average. However, excess risks would be 2–7 times higher in girls than in boys (for non-head scans), 1.5–3 times higher in neonates than in adolescents (for all scanned body parts), and also widely vary according to the CT protocol and indication.

Those risk projections are inherently limited by a range of uncertainties. The most debated issue has been the assumption of a linear no-threshold dose-response relationship, but uncertainties also exist in dose-response model parameters, minimum latency period between radiation exposure and cancer occurrence, population-to-population risk transfer and individual modifying factors. Risk projection must also account for survival probabilities in particular patient populations. Nonetheless, recent large cohort studies in children and young adults have provided useful insights to validate the current assumptions on cancer risks at low doses.

Several national radiology societies have developed CT referral guidelines with a particular focus on children but the majority only considers effective doses which do not account for specific risks in children. Translating patient dose into risk prediction can thus be useful for clinical practice in order to account for patient age and CT protocol for particular indications, particularly for management of diseases involving a long term radiological surveillance.

Age-related biological effects of dental cone-beam CT exposure

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Cone Beam Computed Tomography (CBCT) is a radiographic tool for diagnosis, treatment planning, follow-up and research in dental practice, mostly used in pediatric orthodontics. Although it is considered a low dose imaging modality, it is uncertain that using CBCT is completely risk-free. Investigating low dose effects is of particular interest in pediatric CBCT exposure, since children are more radiosensitive than adults.

As part of the OPERRA-funded DIMITRA project the potential biological effects of CBCT on both in vitro and ex vivo samples were investigated. The main focus lies on pediatric patients, but adult samples were included to check for age-related effects. In vitro low dose X-radiation-induced (0, 5, 10, 20, 50 and 100 mGy) effects were studied in stem cells from the apical papilla, dental pulp stem cells and dental follicle stem cells from three pediatric donors. DNA damage and repair kinetics were analysed by microscopical visualization of DNA double strand break (DSB) markers (ĐH2AX/53BP1) 30 min, 1 h, 4 h and 24 h post-irradiation (p.i.). Ex vivo, DNA damage and repair kinetics were analyzed by microscopical visualization of ĐH2AX/53BP1 in exfoliated oral mucosal cells collected just before and after (30 min and 24 h) CBCT exposure. Saliva was used to detect local changes in oxidative stress levels (8-OHdG and total antioxidant capacity) induced by CBCT in the oropharyngeal region and salivary glands. Sample collection occured just before and 30 min after CBCT exposure.

Preliminary in vitro data show that there is a dose dependent increase in the amount of DNA DSBs 30 min and 1 h p.i.

for doses higher than 20 mGy. This damage is resolved 24 h p.i... DNA damage analysis in oral mucosal cells reveals that no significant increases in the amount of DSBs can be detected after CBCT examination. The amount of DSBs is significantly higher in children than in adults before and 30 min after CBCT exposure. Data from adult patients shows that salivary 8-OHdG levels do not significantly increase after CBCT examination. The salivary antioxidant capacity, however, decreases significantly in adults. Results from pediatric patients show a significant increase in the amount of 8-OHdG after CBCT exposure and, contrary to adult patients, a significant increase in total antioxidant capacity.

In conclusion, preliminary data indicate that low dose X-rays induce increases in DNA damage in vitro, but CBCT examination does not lead to increased DNA damage in oral mucosal cells. Finally, pediatric patients show increased salivary 8-OHdG levels after CBCT examination combined with a slightly increased total antioxidant capacity, whereas adults show a decreased total antioxidant capacity. These data indicate that adults and children react differently to CBCT exposure. By gaining more insight into the biological effects following CBCT exposure current guidelines for CBCT imaging can be adapted, leading to an improved radiation protection of the patient.

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ERPW Session 5: **Medical Radiation Incidents/Accidents**

Wednesday October 11 **11:00 - 12:30** **Ballroom III, IV**

Incidents/accidents in diagnostic and interventional radiology

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Scientific literature shows the existence of large variation of patient radiation doses in diagnostic and interventional X-ray examinations mainly due to differences in examination protocols. However, there are radiation incidents involving the exposure of a patient to a dose much greater than intended. Main reasons for these very high doses are a) lack of knowledge in medical radiation protection, b) poor equipment knowledge and c) use of inappropriate protocols. There are also other causes of accidental exposure, for example failure of staff to properly check the identity of patients. This may lead to radiation exposure of a patient who undergoes an X-ray procedure intended for another patient.

There are data on radiological incidents/accidents in the literature. A well-known accident occurred in 2009, when more than 250 patients in the USA received overdoses from brain perfusion CT. In some patients, deterministic effects (skin injuries and hair loss) were observed after the exposure. However, there are also radiation incidents where radiation doses are not high enough to produce deterministic effects. In these cases, the problem may go undetected.

In fluoroscopically-guided interventional procedures with very long screening time, there is a possibility of cell killing sufficient to result in radiation-induced injuries in certain tissues of patients. Interventional radiologists performing these procedures should be aware of the potential for injuries during these procedures. To avoid radiation overexposure accidents in interventional suites, interventional radiologists in cooperation with medical physicists should establish standard clinical protocols for each specific type of procedure performed.

Accidental irradiation of pregnant patients occurs during the first weeks of gestation. When the uterus is remote from the directly exposed anatomical area, the embryo/fetus is exposed to scattered radiation and its dose is negligible (dose lower than 1 mGy). Radiologic examinations involving the abdomen and/or pelvis may deliver relatively high radiation dose to the unborn child. Situations that may lead to radiation doses higher that 100 mGy are very rare in diagnostic radiology. Abortion due to a diagnostic x ray examination is not justified in the vast majority of cases. After accidental exposure of pregnant patients, conceptus dose estimation is needed.

Incidents/accidents in nuclear medicine

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A significant amount of incidents and accidents from medical radiation exposure have been reported in literature, most of them related to patient's over or underexposure due to non-optimized acquisition protocols or defective equipment. The storage, manipulation and administration of unsealed radioactive sources result in specific potential hazards in diagnostic and therapeutic nuclear medicine. Especially in therapeutic applications, the risk for incidents and accidents is increased due to the high amounts of activity used. Accidents of varying severity are reported. They involve not only patients but also staff members.

Incidents and accidents in nuclear medicine can originate from different phases in the workflow such as the patient reception, the radiopharmaceutical preparation, the calculation of he administered activity, etc. Apart from contamination events, errors in administration, overexposure of patients and problems in radioactive waste management are the most prevalent issues.

The availability of well-defined procedures as well as an appropriate and continuing education of all staff members is essential to minimize incidents and accidents. Moreover, specific duties and responsibilities of the staff involved should be clearly identified. More specifically, medical physicists can play an important role in the management of incidents and accidents in nuclear medicine. (Near) incidents and accidents should be reported and analyzed thoroughly in order to avoid them in the future.

Incidents/accidents in radiotherapy

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The technical and methodological progress in radiotherapy imposes the continuous need to learn from the past accidents and incidents while developing a complex network of checking points and subsequent actions to prevent them in the future. Learning from the past, however, is not enough in the rapidly developing field of radiotherapy involving new techniques and therapeutic approaches and therefore a certain degree of "clairvoyance" is needed to anticipate with large degree what could go wrong in the complex chain of radiotherapy, what is the likelihood for one particular event to happen and what are the expected consequences in a comprehensive and coherent manner that would allow the design of counteractive measures.

This talk aims to present a brief review of the underlying causes and the identified patterns of failure derived from the well-documented accidental exposures of radiotherapy patients and the lessons learnt from them that lead to the current safety checks and preventive actions that are routinely implemented in the clinical practice followed by a summary of the current challenges imposed by the new techniques and treatment modalities and their corresponding prospective approaches for avoiding future incidents and accidents in radiotherapy.

The talk will include few examples of state-of-the-art radiotherapy approaches such as heterogeneous target dose escalation based on integrated multiple functional imaging, radiosurgery and extra-cranial stereotactic radiotherapy as well as particle therapy in relation to the particular challenges they pose from the incident and accident prevention perspective.

The current trends on designing a comprehensive quality management system – the closer one could get to the desired "crystal ball" for predicting the future - that would allow the clinical practice to evolve not only towards a more efficient but also a safer radiation therapy will also be presented.

Retrospective dose assessment of medical radiation exposure: investigation on the ESR dosimetry of nails

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Many techniques for retrospective dosimetry have been developed for assessing past, unexpected radiation exposures. One of the techniques is physical dosimetry wherein solid biological (e.g. nails, teeth, etc.) or fortuitous materials (e.g. mobile phones, accessories, etc.) that a person may carry in his body during the time of exposure are used as samples.

However, only a few studies have been undertaken on the application of physical retrospective dosimetry methods to medicine. Thus, this study attempts to establish a practical approach for assessing radiation doses using a retrospective dosimetry technique for medicine such as radiation therapy. As a first attempt, we investigate the use of electron spin resonance (ESR) signals using fingernail samples.

Before any measurements, fingernail samples were cut to 4 to 5 mm length, soaked in water for 1-hour, and dried and stored in a vacuum desiccator for 8 days. Four different sets of fingernail samples were treated in different ways to obtain radiation-induced signal (RIS), mechanical-induced signal (MIS), and background signal (BKG). Sets 1 and 2 were irradiated to 70 Gy using a LINAC machine (TrueBeam™, Varian Medical Systems) at Hiroshima University Hospital, but further additional cuts (1 to 2 mm length) were given to set 2 after irradiation. Sets 3 and 4 were unirradiated (0 Gy), but set 4 received additional cuts.

Results from the 70 Gy irradiation test showed good and stable reproducibility but the intensity of the signal tends to drop when nails were mechanically stressed. RIS also demonstrated significant instability with time, though it could be affected by unstable BKG and MIS, they must be carefully checked in the future studies. Nails exhibit a very complex and unstable spectrum, further understanding of its ESR signals could improve the suitability of nails as dosimetric material not only in radiological accident but also in medical applications.

Acknowledgements The author would like to thank Prof. Manabu Abe and the Natural Science Center for Basic Research and Development (N-BARD) for the ESR laboratory equipment usage.

An automatable micro-PCC assay for biological dosimetry in cases of large-scale radiation exposures

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In the present work we explore the applicability of cell fusion mediated premature chromosome condensation (PCC) methodology in peripheral blood lymphocytes for the development of a rapid, minimally invasive approach for early triage biodosimetry. Specifically, the main objective was to design a micro-PCC assay that could be applied to very small heparinized blood sample volumes of 50-150μl, using multitube racks or 96-deepwell plates, in order to obtain sufficient lymphocyte prematurely condensed chromosomes (PCCs) for biological dosimetry purposes. The development of such a micro-PCC assay for rapid dose estimation is at present a high priority for early triage in radiation emergencies in cases of large scale exposures. Towards this goal, the various steps of the standard PCC procedure were adapted, and lymphocytes corresponding to blood volumes of 50-150μl were successfully fused with CHO mitotic cells in 2ml round bottom safe-lock tubes or 96-well Deepwell plates of 2ml. The Deepwell plates are more advantageous since the various steps required by the protocol could be applied to all 96 wells simultaneously. The morphology of the lymphocyte PCCs obtained was practically identical to that obtained using the standard PCC assay and it allows, therefore, a simultaneous dose-estimation for at least 2x96 blood samples. In addition, the analysis of radiation-induced excess PCC fragments using Giemsa stain is simple and cost-effective. Interestingly, the use of only 1.5ml of hypotonic solution and the fixation of cells twice with 1.5ml of Carnoy's fixative in the 2ml tubes offers high quality PCC images. In cases of overexposed individuals whose blood samples arrive in the lab at least 10h after exposure, the micro-PCC assay was also successfully combined with fluorescence in situ hybridization (FISH) using simultaneously centromeric/telomeric (C/T) peptide nucleic acid (PNA) probes, for the accurate scoring of dicentric and centric ring chromosomes in lymphocyte PCCs. Absorbed dose estimation, by the analysis of Giemsa stained excess PCC fragments or C/T FISH stained dicentrics in lymphocyte PCCs, was facilitated using appropriate calibration curves constructed in our laboratory. The results obtained and the advantages of using an automatable micro-PCC assay, which will pave the way to the subsequent automation of the assay' s workflow for early triage biodosimetry, will be presented.

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ERPW Session 6: Internal Dosimetry

Wednesday October 11 **11:00 - 12:30** **Ballroom V, VI**

Child and adult thyroid monitoring after reactor accident: recommendations from European specialists

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In case of a nuclear power point accident radio-iodine is a major release and of major concern since it is responsible for an increased risk of thyroid cancer, particularly for children. Iodine internal exposure can be assessed quickly and accurately thanks to in vivo monitoring, for that purpose the radio-iodine burden is measured with detectors in front of the thyroid. However, one of the major gaps identified after the Fukushima accident is the lack of child specific calibration for such measurements.

The CAThyMARA (Child and Adult Thyroid Monitoring After Reactor Accident) project was funded by the European Commission to issue recommendations regarding large scale thyroid in vivo monitoring in case of emergency. The project gathered 42 co-workers from 13 European institutes.

The work focused on the following items.

- Review of international recommendations regarding thyroid monitoring.
- The state of emergency preparedness in Europe, especially regarding thyroid monitoring.
- The concerns of European and Japanese citizens regarding the internal contamination monitoring.
- The reliability of affordable dosimeters that could be used by citizens to carry out their own thyroid monitoring.
- Intercomparison of thyroid measurements, for that purpose child thyroid phantoms were circulated in Europe and measurements were carried out with spectrometric and non-spectrometric devices.
- Establishment of ready-to-use data to interpret thyroid measurements. For that purpose different age classes, the fetus case, several radio-iodine isotopes and the case of iodine prophylaxis were considered.
- A study of the parameters influencing thyroid monitoring, parameters such as the counting distance, the thyroid size and the contribution from other organs were considered. The study was carried out by Monte Carlo calculations.

The conclusions from these work items were given in separate reports and used to issue recommendations.

The main conclusion of these recommendations and the salient results of the project will be presented.

Acknowledgements This work has been supported by the OPERRA – CAThyMARA project (FP7-Fission-2013 project num. 604984) within the 7th Framework Programme. The Eurados Network and particularly the WG7 "Internal Dosimetry" is thank for its support. The LEI laboratory of IRSN and particularly E. Cale, T. Fleury and E. Hatil are thank for efficient and fast manufacturing of sources.

Medical aspects of internal dosimetry

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Medical application of radioactive nuclides is used fairly often in therapeutic and diagnostic procedures in medical care. The variety of possible applications as well as the number of applications is increasing since a number of years. To generate the optimal radiation protection while achieving the needed diagnostic information or while applying a sufficient therapeutic dose where needed it is necessary to determine information about the internal dose distribution for the patients. This is also legally requested for introducing new radiopharmaceuticals. Although, the patients are investigated anyhow, it is often disturbing the medical procedures to gather additional data for determining the activity distributions or patients might be uncooperative due to their illness. The patient variability, the necessary accuracy require to investigate uncertainty and sensitivity of special parameters used for predicting time courses of activity distributions. If all those preconditions are taken into account carefully it is possible to optimise therapeutic doses on an individual patient level or optimise diagnostic procedures as it will be shown on clinically relevant examples like Iodine therapy and 18F - choline diagnostics.

Quantification of uncertainty on lifetime dose assessment for workers occupationally exposed to uranium intakes through a EURADOS intercomparison

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Recently, several epidemiological studies were conducted to identify potential health effects of incorporated radionuclides. To achieve this, exposure of individuals was quantified through doses assessed mainly from urine bioassay analyses carried out to verify the absence (or presence) of incorporated radionuclides in the workers' bodies.

However, data gathered to document workers' intakes were collected to demonstrate compliance with regulatory dose limits rather than for individual risk assessment. Thus, a large portion of bioassay data is recorded as below a facility's administrative limit or the detection limit (DL) of the measurement technique leading to significant uncertainty below regulatory dose limits. Moreover, exposure conditions, gathered in a Job-Exposure Matrix (JEM), are known with variable precision depending on workplace and time of exposure. Therefore, a large panel of exposure scenarios could be used to reconstruct lifetime doses generating significant uncertainty that is difficult to quantify.

In order to quantify the overall uncertainty on the basis of operational data, three cases of occupational uranium exposure were recently distributed inside EURADOS Working Group 7 on Internal Dosimetry for the purposes of an intercomparison exercise aiming:

- to compare dose assessment protocols of the different participants,
- to identify sources of uncertainty, and
- to discuss methods to assess uncertainty on dose.

16 participants estimated committed effective dose, equivalent doses to the lungs and to the kidneys for at least one of the three cases. Case 1 represented a worker with a large number of bioassay results and several recorded incidents; Case 2 had only one out of 19 results higher than the DL and this result was obtained at a time when exposure was not possible according to the JEM; the 75 bioassay results for Case 3 were all below the DL. Monitoring data were collected over 16 years for Case 1, 7 years for Case 2 and 13 years for Case 3.

There was a wide dispersion of the assessed doses for each case, higher than the factor of three usually acknowledged for uncertainty of internal doses. From the description provided by the participants, the protocols to evaluate doses were reviewed in detail and sources of uncertainty along with reasonable modelling assumptions were identified. The influence on the dose of the different uncertainty sources will be estimated by carrying out a sensitivity study comparing doses assessed following different but reasonable modelling assumptions identified in this intercomparison. Finally, this work will be used as a basis for defining guidelines to harmonize the reconstruction of lifetime doses for epidemiological studies.

Radon dosimetry and lung cancer risk assessment for workers: ICRP's approach

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The International Commission on Radiological Protection (ICRP) has recently published two reports on radon exposure; Publication 115 on lung cancer risks from radon and radon progeny and Publication 126 on radiological protection against radon exposure. In its review of epidemiological data on radon-induced lung cancer, ICRP observed an increase in the nominal risk coefficient for radon by about a factor of two in comparison to its previous publication in 1993 (ICRP65). Accordingly, the upper reference level (URL) for radon in dwellings reduced from 600 Bq.m^{-3} to 300 Bq.m^{-3}. On the basis of a consistent and integrated protection strategy, ICRP recommended the same URL of 300 Bq.m^{-3} for workplaces. A graded approach was also recommended for workplaces where a dose assessment is required in certain situations. In its forthcoming publication on Occupational Intakes of Radionuclides (OIR) document, effective dose coefficients for radon and thoron will be provided. These will be calculated using ICRP reference biokinetic and dosimetric models. Sufficient information and dosimetric data will be given so that site-specific dose coefficients can be calculated based on measured aerosol parameter values. However, ICRP will recommend a single dose coefficient of 12 mSv per WLM (working level month) for inhaled radon progeny to be used in most circumstances. This chosen reference value was based on both dosimetry and epidemiological data. In this presentation, the application and use of dose coefficients for workplaces are discussed including the reasons for the choice of the reference value. Results of dose calculations for indoor workplaces and mines are presented. The presentation also describes the general approach for the management of radon exposure in workplaces based both on ICRP recommendations and the European directive (2013/59/EURATOM).

ERPW Session 7:
What are the Evidences for Trans/Multigenerational Radiation-Induced Effects and are They of Concern?

Wednesday October 11 **14:00 - 15:30** **Ballroom III, IV**

Do changes in oxidative stress response, photosynthesis and whole genome methylation induced in plants exposed to enhanced radiation for multiple generations persist in a transgenerational setup?

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The impact on plants of long-term (multi- and transgenerational) exposure to radiation coming from nuclear accidents like Fukushima and Chernobyl is investigated at different levels of biological complexity from the individual (phenotypical and developmental differences) down to molecular level (changes in gene expression and in DNA methylation). Ionising radiation can induce genotoxic effects by interacting with DNA either directly or indirectly and as such can induce DNA damage, oxidative stress and lead to alterations in proteins and lipids. Methylation is one of the epigenetic mechanisms that is involved in the expression of genes and is said to be important in the induction of transgenerational memory in different organisms. Additionally a decrease in global methylation may lead to DNA instability and contribute to mutations and chromosomal recombinations.

In 2016 a field campaign was performed in both Chernobyl (CEZ) and Fukushima affected areas (FEZ). Annual Brassicacea plants, Arabidopsis thaliana and Capsella bursa pastoris in CEZ and FEZ, respectively, were sampled alongside a gradient of enhanced radiation ranging from 0.5 to 50 µGy.h-1. In addition seeds from A. thaliana were harvested in the CEZ and were compared in the lab with plants with different exposure histories: either A. thaliana col 0 stock or plants that were previously exposed to gamma dose rates (delivered by a Cs-137 source) ranging from 20 to 400 mGy.h-1 for 14 days and this in a multigenerational setup for three subsequent generations (F0-S1-S2) or in a transgenerational setup where plants were not exposed for one generation.

The plants were scored for total methylation, photosynthetic capacity and oxidative stress markers as well as germination rate and root growth. In general higher differences are found in plants exposed in a multigenerational setup than in a transgenerational one. The field plants did not show any abnormalities that could be correlated with the exposure gradient although some delay in flowering was observed in plants from medium and high radiation levels. The level of total DNA methylation could not be linked to the radiation gradient present at the different sites. High variation in DNA methlylation in field samples can possibly be attributed to differences in developmental stage of the collected plants. A first indication of the possible involvement of a changed methylation in adaptation of plants to radiation was found in the lab-exposed plants. Global DNA methylation in lab exposed A. thaliana plants showed a significant increase which was both dose and generation dependent. Significant changes in transcription of methylation regulating genes were also measured in the different generations. Highest differences were present in the S1 generation but seemed to be reduced in the S2 generation.

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Investigating chronic low-dose ionising radiation (LDIR) in higher plants: transgenerational effects on morphology and physiology

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Introduction

Significantly less is known about the effects of low-dose chronic exposure to ionising radiation (IR) on plants than the effects of acute high doses. The importance of this lack of understanding is exemplified by the few studies of chronic low-dose effects that focused on genetics and epigenetics, which have potentially profound implications for environmental radioprotection. Renewed interest in nuclear power production and management of legacy and future radioactive waste has led to debates about the "no effects" exposure threshold and consequences for non-human biota. The current threshold for radiation dose having "no detrimental effect to populations" for terrestrial plants is 10 $mGy.d^{-1}$ (IAEA, 1992) and this is now being challenged by researchers. In a long-term experiment that examines morphology and physiology of plants exposed to IR, six generations of Arabidopsis thaliana have been exposed under controlled conditions to soil activities (90 $kBq.kg^{-1}$) comparable to those found in parts of the Chernobyl Exclusion Zone (CEZ) (30 $uGy.h^{-1}$). It is believed that no previous experiments have been carried out in which morphological and physiological parameters have been examined for LDIR in Arabidopsis over six generations. A novel experimental protocol has also been developed for the purpose of analysing root system development in situ. Enzyme activity and metabolite levels were measured as an indicator of antioxidant production in plants under IR stress. E. sativa seeds flown on the International Space Station for a prolonged stay of six months and sent back to Earth provided data on cosmic radiation as a source of radiation stress to plants.

Results and Discussion

Results after first three generations indicated differences between all treatments in morphometric parameters, including fluctuating asymmetry of leaf morphology. Results for developmental stage analysis and physiological endpoints after three generations will be presented. Further investigations are ongoing and on the poster, the results of six generations of exposure will be described as appropriate. These will include the effects on roots as well as shoots.

Conclusions

Growing plants for multiple generations in chronic LDIR produces plants that are not the same as those not exposed. The findings show that even though plants complete life cycles in radioactive conditions and produce virile seeds, overall development is altered. The use of a hydroponic tank system is useful as a non-invasive analytical technique for morphometric data generation for plant roots in situ. Cosmic radiation may have effects on plant development and further research is required in this area.

Acknowledgements This work is funded by a universities partnership with the Natural Environment Research Council (NERC), the Environment Agency (EA) and Radioactive Waste Management Limited (RWM) under the Radioactivity And The Environment (RATE) programme. Seeds kindly donated to the project by the European Space Agency/Royal Horticultural Society. Additional thanks to the Biosphere Impact Studies Unit at SCK•CEN.

Molecular and metabolic mechanisms of transgenerational effects of radionuclides in Daphnia

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Understanding how radioactive contaminants affect species from the molecular to the population levels of biological organization is a major research goal in radioecology. Mechanistic links among the observed perturbations are necessary to predict consequences for survival, growth and reproduction which are critical for population dynamics. Time scales at which such links are studied are rarely ecologically relevant. Multigenerational toxicity studies which are much more relevant to natural biota remain scarce.

With its short life cycle, the cladoceran crustacean Daphnia magna is suitable for studying contaminants effects over several generations. Multigenerational toxicity tests were conducted with depleted uranium (U), americium-241 (Am-241) and cesium-137 (Cs-137), representing respectively a dominantly chemotoxic metal, an alpha internal contamination and a gamma external radiation. DNA alterations were analyzed in daphnids exposed to depleted U and Cs-137 using a RAPD-qPCR technique. Further studies of DNA methylation are currently in progress in order to investigate the role of epigenetic processes in the transmission of effects from daphnids exposed to Cs-137 to their unexposed progeny. Reduction in body size and fecundity induced by depleted U, Cs-137 and Am-241 were analyzed using the Dynamic Energy Budget theory applied to Toxicology (DEBtox). Modelling was performed using a Bayesian framework, in order to properly address uncertainty in parameter estimations and model predictions, and to extrapolate from DEBtox outputs to population responses.

Experimental results showed in all cases that toxic effects on survival, body size, fecundity increased in severity across generations, demonstrating that measured effects in one generation might not be representative of toxicity in the following offspring generations, and ultimately of the population response. Studies of DNA damage demonstrated that molecular alterations were accumulated in daphnids exposed to depleted U and Cs-137 and transmitted to their progeny. Such alterations were interpreted as the underlying mechanism causing the increase in effect severity over generations.

Modelling results suggested that each contaminant induced the same metabolic modes of action in D. magna as in other tested species, including the nematode Caenorhabditis elegans and the zebrafish Danio rerio. For example, depleted U primarily affected food assimilation. This mode of action was confirmed by complementary analyses of carbon assimilation and histological alteration of the digestive epithelium in daphnids. DEBtox models considering the accumulation and transmission of genetic damage were used to analyze toxic effects over generations and explore the mechanisms involved in the transgenerational increase in toxicity in daphnids exposed to depleted U, Cs-137 and Am-241.

Zebrafish exposure to environmentally relevant concentration of depleted uranium impairs progeny development at the molecular and histological levels

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The concentration of depleted uranium (DU) in the environment is expected to increase due to anthropogenic activities, posing potential risks on ecosystems. The effects of chronic exposure to DU at concentration close to the environmental protection standards (0.3–30 µg DU/L) are scarcely characterised. Genomic alterations caused by low doses of pollutants can potentially propagate over generations, but how these effects may affect the health of the progeny remain uncertain for the vast majority of toxicants. We describe the transcriptomic effects of a chronic exposure to 20 µg DU/L during 10 days on adult zebrafish (Danio rerio) organs, the brain, the testis and the ovaries. The potential multigenerational effects of DU were also assessed on the progeny of the adult exposed fish at the two-cells stage and after four days of development. The results highlight generic effects on the cell adhesion process, but also specific transcriptomic responses depending on the organ or the developmental stage investigated. The analysis of the transgenerational effects of DU-exposure on the four-day zebrafish larvae show a deregulation of gene coding for the ATPase complex and the increase of intracellular stress sensed by protein chaperons. These data are confirmed by transmission electron microscopy data showing an impact on the ultrastructure of both the mitochondria and the muscles fibres. The results presented in this study support the hypothesis that a chronic parental exposure to an environmentally relevant concentration of DU could impair the progeny development with significant effects observed both at the molecular level and on the histological ultrastructure of organs.

From DDREF to EDR - what the history of LNT indicates

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The question, how is the biological effects caused by low-dose/dose rate irradiation, is unanswerable by direct epidemiological analysis which requires huge scale cohort. However the ethos of science will make scientists to seek for its solution: For example, the so called Mega-mouse project came out just at the time when LSS was planning to estimate inheritable mutations in atomic bomb survivors. Muller and Neel, who played leading role in human genetics, discussed on the hereditary effects and arrived at the agreement to conceive the "mega-mouse project", which was performed by Russell at Oak Ridge. This is based on the idea of genetic effect the across-species comparison, humans, mice and flies, using the concept of doubling dose. Almost 10 years after, the mouse data made clear the positive evidence of dose dependent mutation rate, which is to be compared with the negative human data. Thus the LSS's findings suggested that the effect to human is not very higher than the one of mice. Neel proceeded to analyse the genetic effect of radiation for human, mice and Drosophila. Of course he knew that there are enormous differences among them, in duration of life, number of germ cell divisions, reproductive strategies and the spontaneous mutation rate. He emphasized the importance of so called "doubling dose" and found that we can convert the mutation frequency of mice into the one of human by using some scaling factor. This set the principle of radiation protection, since inheritable mutations may be less than the cancer health effects.

They also found:

- For lower dose rate, the mutation rates is more reduced.
- The longer the time interval between the irradiation stops and the mating time, the stronger the mutation frequency is reduced, showing an evidence of repair effects. However the dose rate effects were accounted only by introducing DDREF. This is a challenging trial towards a unified understanding of biological effects caused by radiation. Unfortunately scientists at that period, missed the importance of dose rate effects; if they were careful enough, they would have found explicit dependence of mutation frequency on dose rate.

Let us revisit the mouse data and constructed a model) by taking account of dose rate dependence explicitly. We call this Whack-A-Mole (WAM), symbolizing "ongoing battle of security system against mole". The model is very successful to reproduce the mice data and also those of other species including plants. More interesting outcome is to introduce the concept of "equivalent dose rate" (EDR) which converts the biological sensitivity index appearing in the spontaneous mutation into "equivalent dose rate". The spontaneous mutation is on the other hand can be related with the so called "evolution velocity", leading us a unified description of mutation across the species. This may help to set the radiation protection policy of biological risk of long term, low dose rate exposure.

ERPW Session 8: Biomarkers and Cohorts Suitable for Exploring Low-Dose/Low-Dose-Rate Exposure Effects and Individual Susceptibility (Humans, Animals and Plants)

Wednesday October 11 **14:00 - 15:30** **Ballroom V, VI**

Cohorts for radiation research with focus on low-dose/low-dose-rate exposure effects and individual susceptibility

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Epidemiological cohorts are key infrastructures for radiation research and for the derivation of radiation protection standards, as exemplified by the life span study of Hiroshima and Nagasaki A-Bomb survivors, who received low to high doses from acute external exposure to photons and neutrons in 1945.

Many other cohorts have already provided, and still have potential to provide further, essential information on the effects of widely differing conditions of exposure to ionizing radiation (notably at low doses and low dose rates), whether these effects are cancerous or non-cancerous. In the frame of the European Network of Excellence DoReMi, more than 50 cohorts with potential to provide answers to key current questions in radiation protection were identified. They include cohorts of subjects medically, occupationally and environmentally exposed to ionizing radiation.

Cohorts of nuclear workers provide unique information on health effects following chronic external (e.g.: INWORKS) but also various internal (e.g.: Mayak workers, uranium miners) exposures to low doses at low dose rates in adults. Environmentally exposed cohorts have provided essential information on the effects of accidental (ex: Chernobyl fallout) or natural (ex: domestic radon) exposure to radiation in the general population, including children. Medically exposed cohorts also cover populations of all ages and are particularly well suited to study the effects of fractionated exposures and the potential modifying effect of preexisting medical conditions.

Several aspects of individual susceptibility to radiation have already been studied, and can be further explored, in retrospective cohorts. These aspects include age, gender, exposure to other risk factors than radiation (e.g.: smoking, iodine deficiency) and genetic background (e.g.: BRCA1/2 gene mutation). Potential to explore possible interactions between chemical and radiological exposures is developing, for instance in some occupationally exposed cohorts with job exposure matrices documenting chemical exposures. Biological specimens collected in retrospective cohorts, medical records of past biological analyses and information on pre-existing conditions (prior to radiation exposure) can also be used to study various aspects of individual susceptibility to radiation.

In addition, prospective cohorts can further strengthen the potential to explore individual susceptibility to radiation, through the repeated collection of biological material, and documentation of the exposome taking advantage of the newest techniques. Reflections conducted in Europe as part of DoReMi and OPERRA on molecular epidemiology (both within and outside the low-dose radiation field) will be discussed.

Biomarkers for radiation research with a focus on human susceptibility

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Biomarker discovery is common but the validation required for implementation is rare. Validation requires access to multiple cohorts with well annotated data and linked biospecimens, which are difficult to build from populations exposed to low doses of radiation. Hence, biomarkers of susceptibility remain focused on discovery and based on laboratory research or patients exposed to radiotherapy. There is a need for better consideration of the need for assay development that ensures transferability of assays between laboratories. Standardised operating procedures should be developed early in the process of biomarker development and a requirement for publication should be to include assessments of assay repeatability, reproducibility, assay dynamic range and biomarker distribution within a population. The latter development work needs to be followed by assessment of biomarker inter-laboratory reproducibility and performance in multiple cohorts including validation of relevant cut-off values. There is a need for better consideration of the need for large collaborative projects that address issues of building de novo large cohorts that include collection of standardised data and biospecimens to allow for the assessment of performance in multiple populations. Examples from the high dose field for developing large multi-centre cohorts are the Radiogenomics Consortium and the EU funded REQUITE project. Arguably the best validated biomarker of susceptibility is the radiation induced lymphocyte assay. A limitation of focusing on radiotherapy cohorts is the multiplicity of endpoints that are used as a measure of radiation susceptibility. Given that cancer induction and cardiac toxicity are probably the most relevant adverse effects of radiation exposure, the low dose field would benefit from concerted efforts to build multiple cohorts of cancer patients at risk of second malignancies or cardiac toxicity following radiotherapy.

Cognitive and cerebrovascular effects induced by low dose ionizing radiation 'CEREBRAD'

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Epidemiological evidences about the occurrence of late cognitive and cerebrovascular diseases due to exposure to radiation early in life (in utero or during childhood) are scarce. Nevertheless, A-bomb survivor data indicate a linear dose-response curve with a threshold around 200 mGy. Thus, raising the concern regarding the uncertainty of low-dose radiation, which is in part due to the lack of sufficiently large cohorts, combined with a lack of understanding the underlying mechanisms. Moreover, the increasing use of radiation in medical diagnostics urges the need for appropriate research to define precisely the effect of low dose radiation on the brain. The FP7 CEREBRAD project for cognitive and cerebrovascular effects induced by low dose ionizing radiation (grant agreement n°295552), aimed to gather sufficient scientific evidence to increase the statistical power of epidemiological data. Thus, epidemiological evaluations of the risk of cerebrovascular disease following low dose exposures (Excess of Odds Ratio (EOR) of stroke per Gy of average radiation dose to the cerebral arteries, was equal to EOR/Gy = 0.49 (95% CI: 0.22 to 1.17)) based upon a cohort of survivors of childhood cancer receiving radiation therapy before the age of 5 year. While cognitive impairments have been evaluated in a medical and in in utero exposed cohorts from Chernobyl. The project aimed in addition to explain the related cellular and molecular events modulated early after exposure and most probably responsible for late cognitive and cerebrovascular diseases. The shape of the dose-response curve for cognitive impairments in animal models shows a linear dose-response curve with age-dependent sensitivity. In addition, when radiation is combined with other environmental toxicants, we believe there might be no threshold below which no effects are observed. Interestingly the cellular and molecular investigations revealed obvious effects of low-dose ionizing radiation 'LD-IR' on the brain at multiple levels. In general, we could observe a clear dose-dependent effect and could unveil different anomalies induced by the lowest X-ray dose studied (0.1 Gy) in terms of cognition, cell death and neurogenesis. Finally, mechanisms acting at low doses are different from those at high doses, while, processing of the late response could in part be mastered through epigenetic events, requiring thus additional future investigations.

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Development of quality assurance guidance and procedures for collecting a biobank of samples patients exposed to medical radiation

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Molecular epidemiology is needed to investigate the health risks associated with low dose/ dose-rate radiation. These kinds of studies require integration of epidemiology with biomarkers or bioassays of individual exposure and effects or susceptibility to ionizing radiation. Medically exposed patients provide an ideal group for the studying and validating biomarkers in vivo. However, obtaining high-quality samples from patients requires careful planning and co-operation between several professionals. We have explored the requirements of a high-quality biobank of patient samples with dosimetric data and collected a small set of samples according to a protocol developed based on these requirements.

We collected blood samples from men receiving radiotherapy for treatment of prostate cancer and from men having computed tomography scans of the abdominal region. Also, collection of hairs from head and pubic area was tested as a non-invasive sampling method. Samples were collected and handled within the routine hospital operations, which was an important practical issue to be considered in the protocol. For example, timing of venipunctures had to fit the treatment schedule of the patients. The available working time of the biomedical laboratory scientists handling the samples was also limited, which also affected the choice of methods to handle the samples. An essential part of the biobank is to provide material for various analyses which may not be known in detail beforehand. Our samples include frozen plasma (collected using two different anticoagulants, EDTA and sodium heparin) and lymphocytes. One-step mononuclear cell preparation tubes (CPTs) were used to collect lymphocyte samples. The use of these tubes increased the reproducibility of the samples and also was cost-efficient because the time needed for handling of the samples was reduced. An important aim was to have viable cells after freezing and thawing and extra attention was given on this. Before sampling was started, the number and viability of lymphocytes using CPTs was tested. Also, tests on viability and mitogenic activation of the cells were carried out using frozen cell samples shipped in dry ice for approximately 20 hours. The method selected proved to be useful for this kind of purpose. The background information, details of treatment and dosimetric information was available from hospital registries. Dosimetric evaluation of out-of-field doses has been carried out. Patients have also given a separate informed consent which allows us to deliver the samples to the Biobank of Eastern Finland in the future. When delivered to the Biobank the samples can be linked to other registries and other available information on these patients. Samples owned by the Biobank are available for researchers based on a research plan approved by the board of the Biobank.

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ERPW Session 9:
Use of Observatory Sites for Integrated Long-Term Research Activities

Wednesday October 11 **16:00 - 17:00 Ballroom III, IV**

RED FIRE: Radioactive environment damaged by fire: a forest in recovery

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Severe and acute radiation from the Chernobyl accident killed coniferous trees in a 4-6 km^2 area of forest. This area, now known as the ‹Red Forest›, subsequently regenerated with understorey vegetation and deciduous trees. In July 2016, a fire burnt c.80% of the Red Forest presenting a unique opportunity to study the effect of fire on radionuclide biogeochemistry and the impact of radiation on the recovery of forest ecosystems exposed to a secondary stressor (fire).

The objectives of RED FIRE are to: (i) assess the impact of fire on radionuclide behaviour by determining changes in radionuclide mobility in soil; (ii) determine if there is any impact of radiation on the recovery of the forest ecosystem. To achieve these objectives we are using approaches novel to radioecology: bait lamina sticks to measure soil biological activity; aerial drone vegetation and contamination mapping; wildlife camera traps and bioacoustic recorders.

RED FIRE is building upon pre-fire baseline measurements collected by the TREE project and collaborating Ukrainian scientists. This gives an opportunity to contrast pre- versus post-fire ecosystem states.

Fractionation, solubility and mobility

Soil samples have been collected from burnt and unburnt areas of the Red Forest in September 2016 and twice in 2017. These samples are being subjected to chemical extraction techniques to investigate changes in radionuclide mobility attributable to the fire and subsequently with time.

Ecosystem recovery

In April 2016 (pre-fire) we deployed bait lamina sticks at 18 sites in the Chernobyl Exclusion Zone (11 in the Red Forest) to investigate soil biological activity across a range of ambient dose rates, 13-220 μSvh^{-1}. Bait lamina sticks are 10 cm long PVC strips with 16 small holes along their length; the holes are filled with bait (food). Loss of bait provides a measure of soil biological activity. In September 2016 (post-fire), we deployed bait lamina at 20 sites in the Red Forest, including the 11 sites previous used. They were re-deployed in spring and autumn 2017.

In September 2016, at each of the bait lamina sites, vegetation cover was recorded using photographs. Sites were marked so that subsequent vegetation recovery could be monitored during 2017 using photographs and on-ground vegetation survey. In March 2017, aerial drone flights were used to provide a photogrammetric analysis of vegetation cover within the Red Forest. Subsequent flights in 2017 allowed changes over time to be monitored.

In September 2016, 20 motion-activated camera traps were set-up on a grid pattern to record wildlife (primarily medium-large mammals) in the Red Forest; they will be in place until autumn 2017. Bioacoustics recorders, co-located at some of the camera sites, will record the soundscape.

Small mammals will be trapped to determine abundance and diversity. Trapped animals will be live-monitored to determine ^{137}Cs and ^{90}Sr activity concentrations. Data will be compared to previous trapping studies.

Acknowledgements RED FIRE (https://www.ceh.ac.uk/redfire) is funded under a NERC Urgency Grant (NE/P015212/1). Deployment of the camera traps was conducted as part of the TREE project (http://www.ceh.ac.uk/tree) which is co-funded by the Natural Environmental Research Council, Environment Agency and Radioactive Waste Management Ltd.

Transfer and effects studies in the Chernobyl exclusion zone observatory site within the TREE project

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In the 30 years since the Chernobyl Nuclear Power Plant disaster, wildlife in the highly radioactive Exclusion Zone (CEZ) has thrived in the absence of humans. The area is now species rich with more than 400 species of vertebrates, many of which are listed in Ukrainian and European Red Books. There is a diverse range of habitats in the CEZ including pine and deciduous forests, grasslands, wetlands, rivers, lakes and abandoned towns. Yet, this site is highly heterogeneously contaminated by many radionuclides and has experienced high-level, acute exposures especially from short-lived radionuclides in the immediate aftermath of the disaster resulting in the death of some species in some areas (e.g. the pine trees in the Red Forest). Dose rates remain sufficiently high in some places that we may expect to observe radiation induced effects on wildlife. Consequently, the long-term exposure of wildlife to varying levels of ionising radiation in the CEZ provides us with unique scientific opportunities to understand the environmental fate, behaviour and effects of radionuclides.

The NERC, Environment Agency and Radioactive Waste Management Limited have funded a 5-year research programme – Radioactivity and the Environment (RATE) – to enhance environmental protection and safeguard human health from releases of radioactivity. One of the funded research projects - TREE (Transfer-Exposure-Effects: Integrating the science needed to underpin radioactivity assessments for humans and wildlife) is using ground-breaking radiological methods to:

- Study the long-term biogeochemical behaviour of radionuclides that may be found in the radioactive wastes planned for geological disposal (e.g. ^{129}I, ^{79}Se, ^{99}Tc, and uranium isotopes which have the potential to mobilise from repositories and migrate to the biosphere). Improving our process models is critical. Using CEZ soils, we test the hypothesis that models based on short-term laboratory studies adequately predict equilibration in soils.

- Assess radionuclide transfer, identified as area of uncertainty for dose assessment models. Transfer predictions often use equilibrium activity concentration ratios (CR) but many of the wildlife species do not have CRs for radionuclides of interest. The CEZ has been used to help fill data gaps and develop new approaches.

- Determine how wildlife utilizes their environment impacts on their exposure. Wildlife camera traps have been used in areas with differing levels of radiation exposure to study the presence of wildlife.

- Study transgenerational and population health relevant radiation effects. Most available data on radiation effects for wildlife are for a limited range of species and based on short-term laboratory experiments. There is also uncertainty over the contradictory findings between laboratory and unrelated field studies. We are using field and laboratory experiments to identity 'acceptable' levels of exposure to ionising radiation.

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Monitoring of contaminated forests from early post-accident phase to long term, an unavoidable tool to assess RNs cycling in forests

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In 2011, 20% of the radionuclides (RNs) released by the Fukushima Daichii Nuclear power plant (FDNPP) accident were spread across the Japanese continental ecosystems. Forests ecosystems cover almost 75% of the highest contaminated area (> 5 mSv y^{-1}). Six years after, radiocaesiums (rCs: ^{134}Cs, ^{137}Cs) remain the main radionuclides present in the environment. An accurate knowledge of rCs behavior from early post accidental phase to long-term is of first importance to determine the role of forests with respect to the risk of further dispersion, wood contamination or utilization of forests as leisure places. In contrast with the Chernobyl nuclear power plant (CHNPP) accident (1986), a lot of monitoring studies in Japanese forest stands started immediately, or few months after the accident. They provided valuable information on the post-accidental early phase, especially regarding the dynamics of canopies depuration mechanisms for which data were lacking. For longer term contamination, data on rCs distribution between forest compartments is scarce and those obtained overtime after Chernobyl still prevail. However, the environmental context (topography, meteorological conditions, ecosystems…) differ between the two accidents and a direct cross transposition from parameters acquired from one context to the other could introduce large uncertainties when modelling rCs distribution dynamics from early phase to long term. The AMORAD project (funded by the Investissements d'Avenir French program) which is in progress since 2013 aims at improving the modeling of rCs in forests and reducing such attached uncertainties. The project aims to better understand the biogeochemical cycles of RNs and their stable isotopes or chemical analogs (i.e ^{133}Cs and K for rCs) to provide valuable information for modeling parameters and to enlarge comparison between ecosystems. The biogeochemical recycling of Cs contamination assessment is based on sites monitoring corresponding to different situation regarding the contamination phase and vegetal species: (i) two Japanese cedar and one oak stands located in the Kawamata prefecture (Japan), 35 km northwest of the FDNPP monitored from July 2011 and related to the early post-accident stage, (ii), two Ukrainian stands (Scots pine and birch) located ↓80 km south-west from the CHNPP, excluding hot particles contamination and related to an apparent steady state situation, (iii) one uncontaminated beech stand located in north east of France and related to an apparent steady state situation (^{133}Cs, only). This work will show the time evolution of rCs inventories obtained for Japanese and Ukrainian stands, in relevant forest compartments regarding to biogeochemical cycling. Chosen examples of flux within forest ecosystems and stable elements (K, ^{133}Cs) distributions which illustrate the differences of distribution dynamics between elements and sites and the necessity of monitoring tools will also be presented.

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Research opportunities at the Belgian NORM observatory site

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The Belgian NORM site is a calcium difluoride sludge heap from the phosphate industry partly covered with vegetation (e.g. pine trees, grasses, shrubs). Contamination levels of ^{226}Ra between 2500 and 3500 Bq kg^{-1} can be found in the soil and sludge, mixed with co-contaminants such as As, Cd, Cr, Cu, Pb and Zn. A part of this site has been made available for the next 10 to 15 years to perform long-term research in a NORM-contaminated terrestrial ecosystem. Permission to access and work on this site can be obtained via SCK•CEN (nathalie.vanhoudt@sckcen.be). The access request and work program will be evaluated by SCK•CEN and the site owner.

Performing research at this site has several added values for the radiation protection community such as (1) generating site specific data that can be used to improve or validate radiological assessment models, (2) studying possible effects in non-human biota present on the site, (3) improving our understanding of underlying processes that determine radionuclide behavior in the environment, (4) comparing laboratory and field data (for transfer, effects in non-human biota, etc.) and (5) using the site as a testing ground for sampling and monitoring strategies to improve assessment, remediation and regulation strategies in order to ensure long-term safety of NORM affected sites.

To ensure efficiency, continuity and sustainability, a working group related to the site was created within the EC-project COMET in order to define common goals and establish joint research actions. Several institutes have already shown interest in the site and common research activities have started.

A monitoring campaign was carried out to map the spatial variability in gamma dose rate. Additionally, a radiological characterisation of 9 soil samples has been performed using gamma- and alpha-spectrometry (e.g. ^{226}Ra, ^{210}Pb, ^{40}K, ^{238}U, ^{210}Po). To evaluate the mobility of the radionuclides in the samples, a validated leaching experiment was performed for U- and Th-isotopes and ^{210}Po. In addition, concentrations of different metals/elements were determined in the soil samples using ICP-MS and XRF. Further investigations will ensure more in-depth knowledge of processes determining radionuclide mobility and bioavailability in soil and sludge.

In the context of understanding and modelling the long-term influence of vegetation on radionuclide dispersion in forest ecosystems, within the EC-CONCERT-project TERRITORIES a pine forest plot will be instrumented with equipment to follow the cycling of NORM and other elements within trees, integrated with monitoring of the energy and water cycles. Additionally, the radionuclide content within seasonal samples of soil, roots, bark, needles and litter will be monitored.

By joining forces to address common research goals and by sharing data and knowledge between scientific partners, efficient high quality research is ensured for the benefit of the larger radioecology and radiation protection community.

ERPW Session 10:
Harmonization of Practices Enabling Patient Dose Repositories

Wednesday October 11 **16:00 - 17:00 Ballroom V, VI**

Current regulatory and technological opportunities

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Article 58 of the new BSS, which shall be transposed by February 2018, states that Member States shall ensure that written protocols for every type of standard medical radiological procedure are established for each equipment for relevant categories of patients and that information relating to patient exposure forms part of the report of the medical radiological procedure. According to Dose Datamed2 report 590 million x-ray procedures per year and according to the OECD 65 million CT exams per year are concerned. The American College of Radiology National Dose Index Registry with more than 800 centres and 25 million CT doses is an example of a national wide dose collection effort.

Today, existing commercial solutions for Dose Tracking allow a multi-modality approach thanks to a strong integration with PACS, RIS, & EMR using DICOM and IHE standards of communication open the way for the collection of a large number of data.

However, dosimetric metrics, structured dose reporting and semantic interoperability remain challenges that have to be addressed in the European context. A work package is dedicated to these issues in the MEDIRAD project. An update will be given on the recent EC Tender project on clinical DRLs for CT where the semantic interoperability issues would be overcome easily.

This context is an opportunity to establish targeted cohorts in the field of very low doses, which should allow further epidemiological studies.

Harmonization of practices in medical imaging: the way forward

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Technological evolution and new scientific developments have driven the health care sector towards an unprecedented increase of its organisational complexity. One of the major contributors to that increase was the development of medical imaging technology.

Since 1895, radiology became one of the main pillars of modern health care and one of the scientific areas that contributed significantly to the understanding and dealing with the disease [(1)]. The radiology body of knowledge has been constantly developing, driven by a permanent technological (r)evolution and is now integrated in a large spectrum of medical procedures [(2)].

It is interesting to observe that 122 years after Roentgen's revolution, there are still persisting problems, similar to those described in 1910 by Eddy German in the United States: "It was difficult to find two operators who were anywhere near in accord regarding technical procedure. Some would advise certain procedures and others entirely different programs" [(3)].

Despite the scientific knowledge and the technological development, the reality described by Eddy German in 1910 still applies to today's practice of medical imaging. The reasons are manifold: (a) the lack of harmonisation of professional practices at all levels; (b) a communication gap between science and professional practice; (c) a delay in integrating the new technology concepts of medical imaging into curricular programmes of health professions; (d) a barrier between manufactures/equipment developers and clinical practice.

The Dose Data Med 2 report [(4)] clearly shows that data collection and analysis is difficult at EU and even national levels, due to the lack of harmonisation of medical imaging procedures and patient categorisation.

There is an urgent need to develop a European coding system for radiological procedures to be used by all member states, as a tool to easily fulfil the requirement of the Directive 2013/59/EURATOM [(5)], regarding the estimation of population dose: "Member States shall ensure that the distribution of individual dose estimates from medical exposure purposes is determined, taking into consideration the distribution by age and gender of the exposed."

This would be a fundamental tool for future population dose studies and would also contribute to the harmonisation of medical imaging and therapy across Europe, giving healthcare providers information for the future planning of health systems. The EU Directive on patients' rights in cross-border healthcare [(6)], calls for a concerted strategy in terms of harmonisation of clinical practices, meeting patients' expectations of the highest quality healthcare.

According to the EURAMED Strategic Research Agenda [(7)], the comprehensive tailoring of imaging and therapeutic procedures in terms of the clinical question, anthropometric and physiological parameters of each patient, especially children, and lesion-specific characteristics is a key challenge that is largely yet to be fully addressed.

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Challenges in developing dose repository systems

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Many healthcare centers collect radiation doses using dose management systems to evaluate dose levels. These systems collect dose data from imaging systems that can be displayed in a variety of formats for analysis. A system is needed to allow comparison of doses collected by an institution with dose levels of other institutions. Dose repository systems are organized databases of radiation doses shared among multiple users. There are many challenges in developing dose repository systems. The creation of these systems is an expensive process; there are technological difficulties, security and legal issues and issues related to coding systems. These challenges will be presented and discussed during this presentation.

There is a need for a European image and dose repository for benchmarking and research. Further, coding is not harmonised in Europe. Developing a harmonised coding system for Europe, integrated in all HIS / RIS systems, and including radiology and nuclear medicine imaging procedures is not only crucial for developing European dose reference levels, but also for providing high quality data for any research program. The Horizon 2020 MEDIRAD (Implications of Medical Low Dose Radiation Dose) project was recently launched to address needs related to health effects of ionizing radiation used in medicine by enhancing the scientific bases and practice of dosimetry and radiation protection in the medical field. MEDIRAD work package 2 (WP2) will develop and operate an integrated imaging and dose biobank to address needs of MEDIRAD researchers.

MEDIRAD biobank will enable the collection, storage and retrieval of de-identified image data and dose data. It will be composed of two basic resources: a) a DICOM repository, suitable for the images and the DICOM dose data and b) a semantic repository for non-DICOM dose data. Moreover, MEDIRAD WP2 will develop a common catalogue for names of procedures, clinical symptoms, anatomical locations and findings, develop integrated structured reporting templates to collect clinical information, radiological findings and radiation dose, integrate coding schemes into these templates, provide a web-based solution for structured reporting and develop tools to evaluate data collections of structured reports for advanced analytics or data-mining.

The MEDIRAD project has received funding from the EURATOM research and training programme 2014-2018 under grant agreement No 755523. More information about the project can be found at http://www.eibir.org/.

ERPW Session 11:
Radioactive Iodine: Gaps and Knowledge Needed for Nuclear Crisis Integrated Management

Wednesday October 11 **17:00 - 18:00** **Ballroom III, IV**

Radioactive iodine: reducing uncertainty of exposure assessment following nuclear emergencies

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Radioactive iodine occurs in various physical-chemical forms in the atmosphere: particle-bound in aerosols and as elemental or organic iodine in gaseous form. During transport in the atmosphere the partition between these forms changes according the environmental conditions. This metamorphosis in the physical-chemical appearance causes a significant uncertainty in the exposure assessment following the spread of radio-iodine after a nuclear emergency.

For inhalation dose assessment the knowledge of all fractions of radio-iodine is of importance. In the filter samples of monitoring networks only the iodine in aerosols is collected routinely. There are reports that more than two thirds of iodine activity might be missed when only the particulate form is registered. Due to the changing partition a simple correction factor would not help much. This contributes to high uncertainty in regard to inhalation dose.

In addition, the ingestion pathway is affected from the iodine metamorphosis. The deposition velocity of radio-iodine is highly dependent from its physical-chemical form. It is reported in studies that the deposition velocities to grass are up to two orders of magnitude higher for elemental I_2 compared to organic iodine and 20times higher compared to particulate iodine. Similar differences were found for spinach and rice plants. The ingestion dose assessment for directly contaminated agricultural products (e.g. leafy vegetables) and indirectly affected products (e.g. milk) is therefore connected with a high uncertainty, because the different forms of radio-iodine is usually not predicted in the assessments.

The various uncertainties in exposure assessment of radio-iodine following nuclear emergencies due to the unknown physical-chemical form are discussed and approaches to reduce these uncertainties are introduced. Especially the activities for reduction of uncertainties in the frame of the CONCERT project CONFIDENCE and the ALLIANCE roadmap working group "Atmospheric Radionuclides in Transfer Processes" are presented.

Reconstruction of accidental radioactive releases: possible contributions of short-lived iodine isotopes to the source term and radiological consequences

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The investigations presented in this paper aim at the reconstruction of radioactive releases from the Fukushima Daiichi nuclear power plant during the first weeks of the accident, which are based on measured local dose rates on-site and nearby. This local dose rate behaviour is characterised by discontinuous "peaks" followed each by a continuous decrease phase. By comparing our findings with severe accident analyses carried out for Units 2 and 3 by GRS within the OECD/NEA project "Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Plant (BSAF)", a better understanding of the accident progression and an independent evaluation of calculated source terms from severe accident analysis are endeavoured.

Our analysis provides expected and even unexpected results with regard to the behaviour of the local dose rate measured in the first three weeks of the accident. A basis nuclide composition of surface contamination was reconstructed from soil samples on-site only available more than a week after the accident began. Unexpectedly, the local dose rate behaviour during the first few days of the accident, especially the four large peaks and subsequent decrease phases between March 14 and March 16, 2011 cannot be explained by this basis nuclide composition while the agreement improves in the last decade of March 2011.

An in-depth analysis reveals that only contributions by short-lived nuclides to surface contamination can explain measured local dose rates. These contributions can be partly attributed to an excess release of I-132, which is continuously produced by Te-132 decay in the core after shutdown. Such an excess release is corroborated by some air activity samples available about 100 km south of the accident on March 15. However, this process is not sufficient to fully explain the local dose rate behaviour in the night from March 14 to March 15. In that time window, only additional short-lived fission products, generated significantly later than reactor shut down, can suitably explain the observations. Recriticality could provide such a generation mechanism. Whether recriticality events could have taken place in Unit 2 during reflooding of the partly damaged reactor core is currently further analysed by different expert's organisations.

The consideration of short-lived iodine isotopes is a prerequisite for inclusion of on-site local dose rate measurements in our reconstruction approach of the Fukushima accident source term. This inclusion enables a higher temporal resolution and accuracy of our results. Implications of our findings on source term estimation and assessment of radiological consequences for emergency management will be discussed.

Acknowledgements This work is funded by the German Federal Ministry for Economic Affairs and Energy under project no RS 1534.

Guidelines for development of monitoring strategies following a radioactive accident

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This presentation presents guidelines for the development of people monitoring strategies that are applicable to severe accident scenarios. These guidelines focus on accidents at nuclear power plants but could also be applied to other scenarios such as deliberate releases.

The guidelines cover monitoring of external contamination and internal contamination including monitoring of iodine in thyroid. Monitoring strategies developed using these guidelines apply to members of the public (children and adults) but can also be applied to emergency workers.

A monitoring strategy should specify:

- who is responsible for carrying out the monitoring,
- the objectives, targets and design of the monitoring programme,
- who should be monitored and at which locations,
- the measurements to be made, the results needed, and
- the practical organisational aspects.

It should also specify how measurements should be processed, interpreted and communicated to the monitored subjects.

Recommendations regarding these issues are discussed considering different types of accidents and different phases of a nuclear power plant accident.

Acknowledgements This work was carried out as part of the CAThyMARA project of the Open Project for European Radiation Research Area (OPERRA) under the Seventh Framework Programme.

Monte Carlo study of parameters influencing thyroid monitoring of I-131 after a nuclear accident

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In case of nuclear emergency following a reactor accident, a big amount of ^{131}I can be expected to be released, thus making a large contribution to the effective dose to emergency workers and population. Since ^{131}I is mainly deposited in the thyroid, the assessment of the retained activity is commonly carried out by in-vivo measurements using spectrometric detectors calibrated with radioactive reference sources and anthropomorphic neck phantom simulating the thyroid gland. Several parameters influence the result of this calibration, in particular, the detection system, the thyroid anatomical characteristics, the measurement geometry or contributions from other organs retaining radioactive materials.

This communication summarizes the main results obtained in OPERRA – CAThyMARA project (Child and Adult Thyroid Monitoring After Reactor Accident) after an exhaustive study based on Monte Carlo simulation considering four detectors (one LE Ge and three NaI scintillators), seven voxel phantoms (male/female adult, male/female child 15 years-old (y/o) and children 1, 5 and 10 y/o) and two thyroid calibration phantoms (IRSN and SCK•CEN). The voxel phantoms have been obtained from HMGU phantoms by scaling the voxel size, to fit the ICRP thyroid reference values for thyroid volume and body height.

The detection efficiency for a given age-group is a function of the measurement distance and can be fitted by an inverse square function. The obtained values have been used to calculate age-dependent calibration correction factors by normalizing the calculated values to the corresponding one for the adult phantom. These factors vary from 0.65 to 0.90, depending on age and distance, and have to be used in order to avoid biased results when applying adult calibration factors to a subject of a different age group.

The thyroid volume varies from 1.7 to 18.8 cm^3 depending on age and gender. In general, the counting efficiency decreases with thyroid volume although it is also affected by the thickness of the overlying tissue. Nevertheless, a nearly linear dependence of efficiency vs. volume is obtained when the differences in thickness are accounted for by using the fitted inverse square function to calculate all the efficiencies at the same distance from the thyroid centre of volume to the front surface of the crystal in the detector.

The dependence of counting efficiency on extra-thyroidal contributions has been calculated for three phantoms (child 1 y/o, child 5 y/o, adult male) and three distances neck-to-detector (5, 10, 15 cm) as a function of the elapsed time after inhalation of an aerosol Type F with AMAD=1 μm. For the collimated detector, the extra-thyroidal contribution after 1 day is 1% for adult, 4% for child 5 y/o and 7% for child 1 y/o. For the uncollimated detectors, the extra-thyroidal contribution after 1 day ranges from 6% (adult) to 20% (child 1 y/o) and from 2% (adult) to 8% (child 1 y/o) after two days.

Acknowledgements This work has been supported by the OPERRA – CAThyMARA project (FP7-Fission-2013 project num. 604984) within the 7th Framework Programme.

Using animal thyroids as ultra-sensitive biomonitors for environmental iodine-131

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In the early aftermath of the Fukushima nuclear accident, large amounts of radionuclides that are relevant to the Comprehensive Nuclear-Test-Ban-Treaty (CTBT) were monitored globally. One key radionuclide in the CTBT verification scheme is ^{131}I with a half-life of 8 days. In our study, we could show that the intake of environmental ^{131}I into the thyroids of animals can be used for verification of the CTBT. Due to continuous accumulation of ^{131}I, its apparent half-life in the thyroid biomonitor exceeds the physical half-life, thus making ^{131}I detectable three weeks longer than using conventional CTBT-grade high volume air samplers. The maximum ^{131}I activity concentrations (in Bq/kg) found in Austrian animal thyroids after the Fukushima nuclear accident could be correlated with the maximum activity concentrations found in air (Bq/m^3) in Austria via a factor of 1.1 x 10^6. In fall 2011, a second (much smaller) accidental release of ^{131}I occurred from a radiopharmaceutical laboratory in Hungary, where this factor was 1.9 x 10^6. Hence thyroid biomonitors offer even some quantitative information for the estimation of the ^{131}I activity concentrations in air.

Reference: Steinhauser, G.; Merz, S.; Kübber-Heiss, A.; Katzlberger, C., Using animal thyroids as ultra-sensitive biomonitors for environmental radioiodine. Environ. Sci. Technol. 2012, 46, (23), 12890-12894.

Chernobyl to Fukushima: what has changed with regard to radioactive iodine monitoring and measurement? What remains to do?

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Airborne radioactive iodine may be of health concern when released during nuclear incident or accident situations. In accident situation, radio-iodine and especially ^{131}I is expected to contribute up to 90% of the inhalation dose. Iodine is highly volatile and reactive and the ratio between the various released chemical forms may change along the route of air masses. Proper inhalation dose assessment requires the knowledge of both gaseous and particulate fractions. Measurements performed after the Chernobyl and Fukushima (FDNPP) accidents provide information about the gas/particle distribution but this twin determination remains relatively rare. Indeed, airborne radioactive monitoring programs mostly rely on aerosol sampling that makes it possible to determine a wide range of gamma rays emitters. This monitoring is not suitable for gaseous species which in the case of iodine requires specific sampling equipment that uses adsorbent like charcoal or zeolite. When monitoring the Fukushima-labeled air masses in Europe, it was noticed that only 30% of monitoring stations where equipped with a gaseous trap. This situation was probably worst after the Chernobyl accident because most of the monitoring programs at that time were inherited from the global fallout monitoring through aerosol sampling.

At short distance i.e., where the concentration level may be harmful, the main existing fraction depends on the event scenario sometimes in favor of the gas phase sometimes not, as reported after the releases from the different damaged FDNPP units, while far from the emission point there is a rather steady state equilibrium leading to 3 to 4 fifth in favor the gaseous form. This ratio was also in the same range after the Chernobyl accident. Based on this range and considering inhalation dose coefficients provided by ICRP and corresponding to the three main physico-chemical iodine species i.e., aerosol, molecular I2 (gas) and methyl iodide (CH3I, gas), it can be shown that the inhalation dose can be under-estimated by a factor of 8 when the gaseous fraction is missing.

Due to the health impact issues it is recommended to increase the number of gaseous samplers collocated with aerosol samplers in order to improve our knowledge about the gas-to-particle ratio and the kinetics of the transfer of gaseous iodine on the particulate phase as well as its deposition velocity. In early 2017, about thirty trace-level ^{131}I detections were reported in Europe. Tiny amounts were not sufficient to quantify the gaseous phase while likely to be dominant. It is thus worthwhile to decrease the detection limit of the gaseous phase. Up-sizing the charcoal trap and homogenization prior to measurement will participate to this challenge. Next upgrade will deal with how to trap separately both gaseous species.

ERPW Session 12:
Dosimetry in Complex Fields

Wednesday October 11 **17:00 - 18:00** **Ballroom V, VI**

Pulsed neutron fields: inter-comparison of various detectors

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Measurements in pulsed radiation fields represent a challenge because intense and short burst of radiation in detectors operated in pulse mode can lead to important underestimations due to the dead time losses. The problem is well known since the forties, but still represents an open research field.

The last generation of particle accelerators is characterized by the production of very intense and short radiation bursts. Examples are the free electron lasers (FEL) or the new pan-European research infrastructure ELI (Extreme Light Infrastructure).

Stray radiation around these facilities is mainly composed by neutrons and photons with a time structure that reflects the one of the accelerated particles. The result is that the radiation detection instrumentation, intended both for radiation protection and beam monitoring, must be designed to cope with radiation bursts whose duration stretches from ms down to tens of fs.

A first intercomparison exercise of active neutron survey meters in a pulsed neutron field (PNF) was undertaken in the framework of the EURADOS working group 11, with the participation of eleven European institutions.

The intercomparison involved a total of 29 instruments, divided in 14 neutron area monitors and 15 active personal dosimeters (APDs) and the measurements took place at the cyclotron of the Helmholtz-Zentrum Berlin für Materialien und Energie GmbH (HZB).

The aim of the measurements was to evaluate the instrument linearity as a function of the radiation burst intensity. The neutron field was produced by shooting a 68 MeV proton beam onto a thick tungsten target. The cyclotron had the possibility of delivering the proton beam in bursts whose minimum duration was 1µs. The burst intensity was varied both by changing the proton current and by increasing the burst duration.

The results showed that standard rem counters operated in pulse mode can hardly withstand a burst dose higher than few tens of nSv. Only specialized instruments designed for working in PNF can extend the dynamic range up to several hundreds of nSv per burst.

On the other hand, personal dosimeters do not show any deviation from linearity. This behaviour was explained considering the pretty low sensitivity of APDs when compared with area monitors.

Acknowledgements A special acknowledgment to EURADOS and in particular to the WG11 that permitted the organization of the intercomparison and partially funded the work

The commissioning of new pulsed high-energy electron accelerator facility SwissFEL in Switzerland from a radiation protection point of view

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The Swiss Free Electron Laser (SwissFEL) is a new large-scale facility currently under commissioning at the Paul Scherrer Institute (PSI). It is foreseen to accelerate electrons up to an energy of 7 GeV with a pulsed time structure. The accelerator can be operated with a maximum charge of 800 pC per pulse and a maximum repetition rate of 100 Hz. With a total length of 720 m, the accelerator consists, in its final layout, of an injector area (gun and booster), three linear accelerating sections, two parallel undulator lines, and several experimental areas. Accessible areas surrounding the accelerator tunnel together with the pulsed time structure of the primary beam, lead to new challenges to ensure that the radiation level in these areas remains in compliance with legal constraints defined by the Swiss radiation protection ordinance.

An online dose rate monitoring (DRPS) system is installed to prevent radiation losses which may lead to exceeded dose guidance values in accessible areas. Since areas surrounding

SwissFEL are accessible by the public, the DRPS monitors the dose rate arising from neutrons inside the tunnel and is opportunely calibrated to indicate the dose rate in accessible areas outside the accelerator vault. This approach leads to challenges for the employed survey instruments, as they are exposed to an intense photon background, the presence of RF fields and short pulsed neutron fields with expected maximal doses of a few µSv per pulse. A commercially available extended range neutron rem counter suitable for measurements in the described conditions is the LUPIN 5401 BF3. A series of measurements have been carried out to verify its dose indication. The presented studies describe the basic concept of the DRPS and results of these measurements.

Diagnostic reference levels of CT radiation dose in whole-body PET/CT: an indian scenario

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Introduction

There are no guidelines or regulations available worldwide to restrict the radiation exposure to the patients undergoing various radiological studies. Many countries have their diagnostic reference level (DRL) in order to achieve optimal image quality of CT imaging with minimum radiation exposure to the patient. However, the same is not available for whole-body CT acquired in PET/CT studies. The utility of CT in PET/CT studies in prevalent clinical practice is not limited only to anatomic localization and attenuation correction, but also in diagnostic purposes. Hence various researchers have tried to generate DRL for CT scan acquired along with whole body PET/CT. In our study, we have tried to generate DRL for CT acquired in whole body PET/CT scans.

Methods

This is a retrospective study approved by local ethics committee. In this study, we have audited whole body PET/CT scan performed in our department on Discovery STE PET/CT scanner, GE medical system Milwaukee, USA. The CT dose index volumes (CTDIvol) of CT scan performed along with whole body PET scans were noted from system generated dose reports. CT protocol: X-ray tube potential for the scan was 120 kVp for all the scan and beam intensity was in auto mA mode from 100mA to 220 mA.

Results

Total 700 patients whole body PET/CT data were analyzed for this study. The average CTDIvol noted in our study was 11.2 mGy. The 60 percentile CTDIvol reported in this work was within one standard deviation range.

Conclusion

Our study shows that in current generation PET/CT imaging where the CT component of PET/CT scan is also used for diagnosis. According to our study DRL for whole body CT in PET/CT study was found to be 11.2 mGy.

ERPW Session 13:
Eye Lens Exposure and Monitoring

Thursday October 12 **09:00 - 10:30** **Ballroom III, IV, V, VI**

The European epidemiological study on radiation-induced lens opacities among interventional cardiologists: final results of the EURALOC project

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The EURALOC project was accepted in the first Operra call in 2014. Low dose radiation effect on the eye lens has been an area of interest in numerous epidemiological studies. The radiation-induced risk has been assessed for different populations and in some cases, an attempt was made to determine a dose-response relationship. The European epidemiological study, EURALOC, was conducted between December 2014 and May 2017 with the objective to investigate a possible dose-response relationship by targeting a sufficiently large study population with reasonably high exposure levels, namely interventional cardiologists (ICs).

In total, 393 subjects have been successfully recruited in the exposed group, they have completed study questionnaires on work history and risk factors for lens opacities and received an ophthalmological examination. As for the control group, 243 subjects have been recruited, completing the same questionnaire on risk factors for lens opacities and ophthalmological examination.

Large efforts have been made to develop 2 approaches to assess retrospectively the cumulative eye lens doses of the recruited cardiologists. The first approach is based on the individual work history in combination with published eye lens dose data, while the second approach is based on individual routine whole body dosimetry and its conversion to eye lens dose. More than 200 dose measurements have been performed in clinical practice to validate both calculation approaches and this study demonstrated that the 1st approach resulted in the most satisfactory results with an average ratio between measured and calculated eye lens dose value of 0.96 [95%CI: 0.87-1.09] for the left eye and 0.50 [95%CI: 0.44-0.56] for the right eye. The added value of the EURALOC dosimetry approach is that for each IC, not a single dose value, but an individual cumulative eye lens dose distribution has been used as input for the statistical analysis of the risk of radiation-induced lens opacities.

All the information collected through the questionnaires could also be used for educational purpose. Two tools were developed having each their own specific target group and capabilities: an educational App for mobile devices for ICs and an eye lens dose calculation tool for radiation protection professionals.

Innovative approaches have been used for the statistical analysis by using a mixed linear regression and polytomous logistic regression approach, which permits a correct modelling of the lens opacities by taking into account the correlation of the soring outcomes of both eyes in the radio-induced risk estimation as well as dose estimation uncertainties. The analyses established a significant impact of radiation dose in the occurrence of PSC opacities with a relative risk for ICs of OR=2.62 (95%CI 1.35–5.08). A linear no threshold model provided the better fit of the lens opacities dose-response relationship with an excess relative risk per Gy equal to 1.31 (95% CI 0.13-3.32).

Acknowledgements The EURALOC project consisted of a large multidisciplinary consortium of epidemiologists, statisticians, medical physicists with expertise in dosimetry and ophthalmologists from 14 partners. Following additional persons also contributed to the project and merit to be recited: Jérémie Dabin (SCK•CEN), Danielle Berus (VUB), Marcel Ten Tusscher (VUB), Sophie Jacob (IRSN), Isabelle Clairand (IRSN), Jad Farah (IRSN), Ulrike Scheidemann-Wesp (UMC), Andrea Hoeck (UKB), Heike Laser-Junga (UKB), Joanna Jurewicz (NIOM), Panagiotis Askounis (GAEC), Zoi Thrapsanioti (GAEC), Danijela Arandjic (VINCA), Renato Padovani (ICTP)

Cataract avoidance with proton therapy in ocular melanomas: need for revised dose volume limits to the lens?

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Background: The lens is a very radiosensitive organ. Consequently, any dose of irradiation involving the head can theoretically give rise to radiation-induced cataracts. Previous clinical and radioprotection studies only evaluated the effect of dose on the whole lens. Proton therapy (PT) is a type of radiation that can spare all or part of the lens due to accurate dose deposition. Objective: To investigate whether a lens-sparing approach was relevant to avoid cataracts in uveal melanoma patients (although never at the cost of reduced tumor control or more dose to the optic nerve and macula). Material and methods: patients were referred for proton therapy from a network of private ophthalmologists and onco-ophthalmologists in private or academic institutions. Between 1991 and 2015, 1696 uveal melanoma patients were consecutively treated with PT. They underwent bi-annual follow-up at onco-ophthalmology centers. Patients without preexisting cataracts or implants were entered in a prospective database. Dose thresholds responsible for cataracts were investigated in small volumes of lens or lens periphery. Correlations between dose-volume relationships and vision-impairing cataracts (VIC) were assessed using univariate and multivariate regressions. DE novo cataracts were assessed as binary data. Lens opacifications and associated vision-impairment were assessed during follow-up by ophthalmologists blinded to the lens dose. Results: After a median follow-up of 48 months, 14.4% and 8.7% of patients had cataracts and VIC within median times of 19 and 28 months, respectively. Median values of mean lens and lens periphery doses were 1.1 (radiobiologically effective dose in photon-equivalent Gy) and 6.5 GyRBE, respectively. The lens received no dose in 25% of the patients. At an irradiated lens volume of less than 5%, there was no significantly increased risk for VIC below a dose of 10 GyRBE. Conclusions and relevance: A lens-sparing approach to prevent radiation-induced cataracts is feasible and results not only in reduced need for cataract surgery but also in better fundus-based tumor control. This has implications for radioprotection rules in terms of lens dose thresholds. Additional studies are needed to better assess the mechanisms of radiation-induced cataracts by correlating radiation targeting and LOCS3 grading.

INSTRA – an integrated lifetime study in mice assessing lens opacities and other biological endpoints after exposure to low doses of ionizing radiation

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There is a need for quantitative data to judge the effects of low dose ionising radiation. In a lifetime study with mice as a mammalian animal model we analysed radiation effects on the eye, especially the ocular lens. We combined these investigations with behavioural analyses and initiated detailed examination of other organs including lens, brain, liver, thyroid and blood.

Young adult mice (10 weeks) of different genetic constitution (wild type and $Ercc2^{+/-}$; Kunze S. et al., PLoS One 2015, 10, e0125304) were whole body irradiated with a single low dose of ionising radiation (0, 63, 125 or 500 mGy) at a low dose rate (63 mGy/min). Lens opacification was analysed monthly by Scheimpflug imaging. At different time points (4 and 24 hours, 4, 12, 18 and 24 months post irradiation) mice were sacrificed and a set of organs were analysed histologically. Behaviour tests were performed 4, 12 and 18 months post irradiation. A significantly altered survival rate and a dose-dependent risk for several types of tumours were indicated by pathological screening.

Over a follow up period of 24 months after irradiation the lens opacification showed a subtle significant dose-dependent increase of lens opacity (~1%), which is smaller than the age effect (~2%). The absence of cataracts was confirmed by histology; there was also no difference in proliferation of the lens epithelia cells or in the differentiation of lens fiber cells. Metabolomic analysis of pooled lens tissue samples, derived from different genotypes, revealed age-dependent changes [e.g., decreased concentration of acylcarnitines (C3 / C18), increased concentrations of sphingomyelines (SM C24.1 / SM C26.1) and glycerophosholipids (PC aa C38.3 / PC ae C30.0)]; the effect of age could not be observed in plasma samples of the same animals. Due to the small sample size, a radiation effect could not be calculated.

Also the analysis of some behaviour tests showed significant dose-dependent radiation effects, particularly in the acoustic startle reflex, the velocity of movement (average speed) and the total distance travelled. The dose-dependent effect increases by age. Preliminary proteomics data on hippocampal extracts hint to a reduced activity of CREB 18 months after irradiation, and to a deactivation of CREB-signaling 24 months after irradiation

Analysis of the thyroid gland revealed no radiation effect on inflammation of the thyroid gland; however, hyperplastic and neoplastic alterations were observed in the irradiated cohorts only.

Future experiments will include transcriptomic analysis of blood cells, investigation of inflammatory markers in the blood and general proteomics in liver; bioinformatics will integrate all the data.

The data revealed so far demonstrated clear long term effects after exposure to low doses of ionising radiation, but the ocular lens does not seem to be one of the most radiation-sensitive tissues.

Acknowledgements The INSTRA consortium is supported by the German Federal Ministry of Education and Research (02NUK045A, B and C).

LDLensRad: Towards a full mechanistic understanding of low dose radiation induced cataracts

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Recent epidemiological studies and reanalyses have indicated that the threshold for formation of radiation induced lens opacities is much lower than previous understanding had suggested. The mechanisms of low dose radiation cataract induction are, however, still highly unclear, and important questions thus remain regarding the scientific basis for protection of the lens. Despite this, a substantial reduction in occupational lens dose limits is currently being implemented within the European Union.

The CONCERT funded LDLensRad project aims to bring together experts from across and beyond Europe to answer a number of key research questions regarding the effects of radiation on the lens, including: the mechanisms involved in low dose radiation cataract formation; the impact of dose and dose rate; the role of genetic background, and whether radiation responses observed in the lens can be viewed as global biomarkers of radiosensitivity. The multidisciplinary team of LDLensRad collaborators will investigate the mechanistic chain of events from the biological responses to the initial radiation insult (including DNA damage and repair and cell cycling effects), the impact in terms of perturbation of lens fiber formation (intracellular communication and proliferative effects), through to the morphological outcomes in terms of formation of lens opacities assessed through life time cataractogenesis studies. These effects will be investigated in a range of radiosensitive and radioresistant mouse models chosen from the literature, specifically: C57BL/6, 129Sv, Ercc2+/- and wildtypes bred on a C57BL/6 X C3HeB/FeJ F1 background, and Ptch+/- bred on CD1 and C57BL6/J backgrounds. The mice will be exposed to doses of 0.5 – 2 Gy Co-60 gamma radiation, with dose rates of 0.3 and 0.063 Gy min-1. These studies will be reinforced by in vitro cellular investigations with a greater number of doses and dose rates, using a range of appropriate cell lines. In addition, the potential for a prospective molecular epidemiology programme using human lenses obtained from workers of the first Russian nuclear facility, the Mayak Production Association, will be explored. This lens biology and cataractogenesis studies will be supported by neurological and pathological analysis of the brain to investigate wider systemic radiation responses and to work towards testing the hypothesis that radiation effects in the lens can be used as an indicator of global radiosensitivity. Detailed statistical modelling will also be employed.

The results of this project will have key implications for radiation research and protection. Concrete outcomes are anticipated to include definitive information regarding the shape of the dose response and dose rate effects, thus advancing knowledge regarding the risk of radiation cataract at low doses. The aims and objectives of the project will be presented, together with preliminary data.

Acknowledgements The LDLensRad project has received funding from the Euratom research and training programme 2014-2018 in the framework of the CONCERT [grant agreement No 662287].

Monitoring of radiation doses during coronary angiography and percutaneous transluminal coronary angioplasty procedures performed using flat panel detector

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Introduction

All fluoroscopy guided cathlab medical interventions use ionizing radiation. The use of ionizing radiation is hazardous for occupational worker performing/ involved as well as for patient undergoing the fluoroscopy guided cathlab procedure. The present study investigated the dose to eye lens of occupational worker during forty coronary angiography (CA) and percutaneous transluminal coronary angioplasty (PTCA) procedures. The fluoroscopy time and DAP readings were recorded for each procedure.

Materials and methods

The present study was performed in Siemens Axiom Artis Zee interventional cardiology unit have monoplane digital flat panel systems with the undercouch X-ray tube geometry and ABC mode. The interventional unit has DAP meter mounted in the X-ray tube housing, which was used for the measurement of ESD in our study. Twenty interventional procedures of CA and PTCA each were observed for the study. The measurement of eye lens dose of cardiologist was performed using OSLD. Three dosimeters were placed on right, midline, left side of eyes. Relevant patient and examination related parameters as patient name, sex age, type of procedure, total fluoroscopy time, DAP meter reading and number of cine series were also recorded.

Results

The patients included in this study were aged between 35 to 78 years and most common age found was 62 years. The average fluoroscopic time and DAP reading observed were 3.62 minutes and 31 Gy.cm2 for CA procedure. For PTCA procedures, the average fluoroscopic time and DAP readings were 17.69 minutes and 75 Gy.cm2 respectively. Further the dose to eye lens of cardiologist observed for angioplasty procedure was 2 to 3 times higher than that for angiography procedure. One of the interesting observations in our study was that the right eye doses were observed higher in angiography procedures and left eye doses observed higher in angioplasty procedures. The explanation lies in the geometry of procedure and exposure condition. It was observed that the interventional cardiologist spent more time in the insertion of catheter in angiography procedures with right eye facing the X-Ray tube. This may have caused the higher dose to the right side placed dosimeter than left or middle dosimeter in angiography procedures. On the contrary, the interventional cardiologist was spending more time in analyzing the acquired images on monitor during angioplasty procedures with the left eye facing the X-Ray tube, which may have resulted in higher dose to the left side dosimeter in angioplasty procedures.

Conclusion

The observed fluoroscopy time and DAP meter reading were found lesser than the European Union data. However, the eye lens doses to occupational staff were observed higher than the data quoted in literature and require urgent attention. The results of the present study highlighted that the new eye lens threshold dose limits may exceeded in interventional cardiology if proper shielding and protective devices were not in place.

Acknowledgements The authors thank Dr. Vijay Pathak, Department of Cardiology, SMS Medical College & Hospital, Jaipur, India for providing support and giving suggestions.

ERPW Session 14:
Individualized Approaches for Radiation Protection

Thursday October 12 **11:00 - 12:30** **Ballroom III, IV, V, VI**

Challenges of individualized radiation protection: identification of individual radiation sensitivity

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Individual variability of radiation sensitivity is of major concern in radiation protection. Individuals and groups of individuals can show differences in radiation sensitivity, depending on various factors such as age, gender, genetic and epigenetic predisposition and lifestyle when exposed to ionising radiation. Radiation protection will have to meet this challenge, including not only scientific knowledge but also ethical considerations.

It can be expected that technical progress in analyzing established biomarkers on the one hand and the availability of new biomarkers with the capability to verify low dose effects in humans on the other hand, a more sensitive and fast identification of the individual radiation sensitivity will be possible in the future. In case radiation sensitivity can be linked to health risks, either for an individual or for a group of persons, radiation protection measurements can be optimized and performed in a more individualized manner. This can affect, for example, decisions about preventive medical checkups, such as X ray and CT examinations, the application of Radon therapies in spas or mines, or individualised protocols for radiation or nuclear therapy.

However, the possibility to classify groups of individuals with regard to their radiation sensitivity will also rise ethical considerations, especially when it is linked to decisions about the free choice of work life and career.

Besides addressing some challenges in individualized radiation protection, an example of improved cytogenetic analysis is presented, enabling to show different age related radiation sensitivity in blood cells of two population groups.

Individual radiation protection approaches in medical applications

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Medical applications of ionizing radiation include diagnostic procedures in radiology or nuclear medicine, interventional procedures in radiology, therapeutic administration of radionuclides and radiation oncology. For all applications, a "justifying indication" has to be guaranteed for each individual patient. If this is not the case, or if - for diagnostic procedures - alternative methods would provide the identical information, than the latter must be chosen. For example, if a patient has a known or expected hyper-radiosensitivity, e.g. for breast cancer induction (BRCA1/2 mutations, family history), the individual screening procedures are adjusted, excluding ionizing radiation and switching to magnetic resonance imaging. Furthermore, there is an individually adjusted patient education and documentation. Moreover, device settings in radiology and radionuclide doses in nuclear medicine are adopted for the individual patient. In radiology, the radiation exposed volumes are clearly adjusted to the regions to be examined in the individual patient.

In radiation oncology, with the developments in medical physics and radiotherapy administration techniques, the physical dose distributions are progressively reaching a higher conformality to the volume that needs to be exposed ("Planning Target Volume", PTV), thus sparing the major and most sensitive (for "deterministic" effects) organs at risk. Radiation qualities (including therapeutic ion beams), tumour total doses, doses per fraction and overall treatment times are chosen for individual tumour (sub)types, thus representing at least a stratification of patients into particular groups. Also, additional chemotherapies or administration of modern, biologically-targeted drugs is adjusted to the biological characteristics of the individual tumour.

The increase in high dose conformality to the target volume, however, is frequently associated with an enlargement of the volumes that receive inhomogeneous intermediate and low radiation doses. For ion beam therapy, this may also refer to exposure to secondary neutrons. This poses a risk of second cancers. Recent analyses, for example on second cancers (lung, breast) after breast cancer radiotherapy [Grantzau et al. 2013, 2014] showed a dose-dependent second cancer risk close to the PTV (0.5 %). Earlier studies [Dörr and Herrmann 2002] yielded comparable results. The very low dose region may in some individual situations be critical as well. However, dose distributions can and are adjusted to also spare the organs and tissues at high risk for the induction of second cancers.

Individual approaches in emergency scenarios

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Individual, retrospective dosimetry is an approach based on estimating the absorbed dose by measuring radiation-induced signals in tissues of an exposed person (referred to as biological dosimetry) or objects which the person had with him at the time of exposure (referred to as retrospective physical dosimetry) The demand for precision of dose estimate will depend on the emergency scenario. Small scale accidents allow to focus on each collected sample, permitting a precise estimate of the dose and exposure conditions. In large scale emergencies, speed is of primary importance, because in view of the expected large scale concern and panic, it will be vital to quickly triage people according to the level of exposure, whereby it will suffice to follow three categories: non-, or minimally exposed (<1 Gy), mildly exposed (1-2 Gy) and severely exposed (>2 Gy). Moreover, if required, a more precise dose estimation will still be possible at a later stage.

A battery of biological dosimetry tools exists, each having advantages and disadvantages regarding precision, speed of dose estimate, signal stability, specificity to radiation and the ability to differentiate between whole or partial body exposure. The choice of a tool will depend on the emergency scenario but also on the available time and resources. No single laboratory has the capacity to run all tools, hence, networking is vital. An important aspect of biological dosimetry which is often underestimated is that it provides a radiation victim with personal information about his/her absorbed dose which is not based on gross estimates, but individual measurements. This aspect provides the exposed person with the vital feeling of trust that he/she is correctly diagnosed.

A short overview of the possible biodosimetric tools for individual, retrospective dosimetry will be given. The tools are being tested and expanded within the biodosimetric network RENEB (www.reneb.net).

Individual Sensitivity: neither the issue or its solution should be thought of as radiation specific

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The requirement for occupational radiation doses to be As Low As Reasonably Achievable (ALARA), promulgated by the International Commission on Radiation Protection in 1977, transformed radiation protection practice. It also led the way to develop similar standards for a range of other occupational hazards.

The radiation world is now increasingly recognising the relevance of individual sensitivity to ionising radiations at occupationally relevant doses, with the real prospect that this will be incorporated into future occupational radiation protection standards. The key drivers seem to be;

Known genetic radiation sensitivity, and gene testing is now feasible.

Radiation risk relates to general cancer risk, including considerations of lifestyle and other exposures

Some specific radiation risks may be much higher in certain human subgroups.

Individual sensitivity to other occupational hazards is well established, but little acknowledged to date, in systems of occupational health regulation. Genetic factors are linked to a wide range of occupational diseases, with end points as diverse as bladder cancer from aromatic amines, dust disease such as silicosis, acute toxicity from pesticides, hearing loss from noise, and chronic disease toxicity from beryllium. There are established genetic links increasing sensitivity to infections that could be acquired occupationally, and even in relation to psychological health. It is conventional to consider workplace hazards in a table of physical, chemical, biological and psychological exposures. There is now clear evidence for some importance of individual sensitivity in health effects in all these areas. In relation to lifestyle, there is a synergy between the more than additive effects of radon and asbestos when either is linked with cigarette smoke. We are also aware high occupational risk in subgroups, for example; Type 1 hypersensitivity to Latex is almost exclusively restricted to those who are strongly atopic.

The ethical, scientific and practical difficulties of standards based on individual sensitivity are huge, with the strong possibility that restricting consideration to radiation induced cancer would not provide a model that is sensible throughout occupational health. It is suggested that ICRP should seek to join with other groups, such as ICOH in setting up a system to look at the issue of individual sensitivity in its entirety.

Reduced contrast volumes in small patients and more uniform inter-patient image quality with personalized contrast protocols in abdominal CT

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Objectives: To achieve consistent contrast enhancement across different BMI-groups, patient tailored volume protocols should be considered. The aim of this study was to compare the effect of a fixed and a patient tailored intravenously injected contrast volume protocol on contrast-enhanced abdominal CT-images with respect to image quality and contrast volumes.

Methods: Data of 77 patients who underwent two contrast-enhanced abdominal CT-examinations were collected. The first examination was performed with a fixed volume protocol; the follow-up examination was performed with a patient tailored volume protocol. Enhancement was measured by two radiologists. Differences in attenuation and contrast volumes were analyzed.

Results: Attenuation was more consistent over different BMI groups in the patient tailored volume protocol compared to the fixed volume protocol. There was a significant contrast volume reduction in women and in patients with low to normal BMI comparing the patient tailored and the fixed volume protocol.

Conclusions: Patient tailored volume protocols can reduce mean contrast volumes in small patients, especially in females. It improves CT-image standardization by harmonizing enhancement across different BMI groups. This avoids administration of inappropriate high contrast volumes in small patients and inadequately low contrast enhancement in large patients.

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Exhibition Hall Floorplan

MEDSQUARE *Booth* **1**

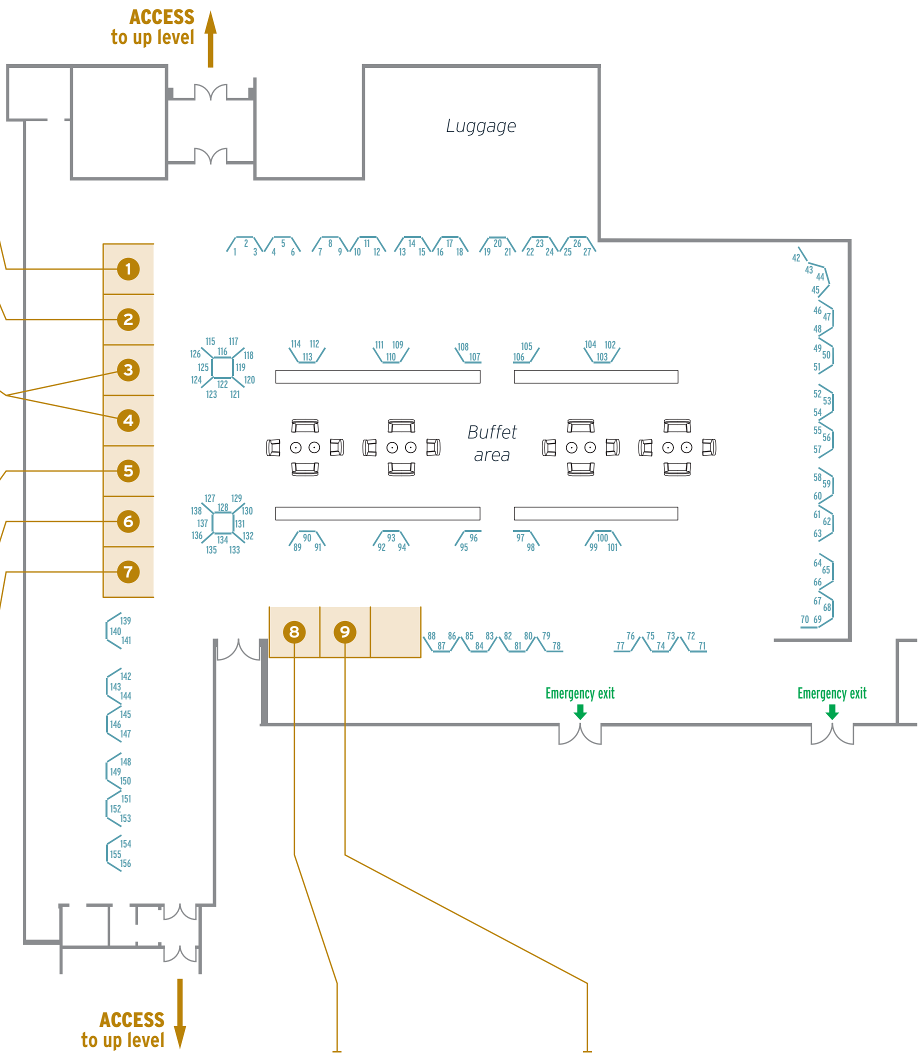
NEOLYS DIAGNOSTICS *Booth* **2**

IRSN *Booth* **3-4**

CHIYODA TECHNOL CORPORATION *Booth* **5**

CEVIDRA *Booth* **6**

SAGE PUBLISHING *Booth* **7**



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Booth **9**
ICRP 2019

ERPW Poster Sessions

ERPW Session 01: **Ethics in radiation protection**

Nº	TITLE	AUTHORS
1	A public facing survey set up within the CONCERT European Joint Programme: gauging the perception of radiation risk	**Sveva Grande,** Sara Della Monaca, Valentina Dini, Alessandra Palma, Paola Fattibene, Antonella Rosi, Tatiana Duranova, Tanja Perko, Christiane Pölzl-Viol, Yevgeniya Tomkiv, Catrinel Turcanu, Christine Willrodt, Maria Antonella Tabocchini, Mauro Grigioni, Simon Bouffler
2	Calculation of radiation detriment: tracing the current ICRP approach	**Enora Clero,** Ludovic Vaillant, Wei Zhang, Nobuyuki Hamada, Nobuhiko Ban, Dominique Laurier
3	CONCERT survey on data management	**Balázs Madas,** Paul Schofield
4	Ethics vs science - Lessons from Fukushima crisis	**Masako Bando,** Takahiro Wada, Yuichiro Manabe, Yuichi Tsunoyama, Hiroo Nakajima, Toshihiro Higuchi
5	Improving scientific literacy among school children through teaching about radiation risk and risk-assessment - the RISKEDU project	**Andrzej Wojcik,** Karin Haglund, Leena Arvanitis, Iann Lundegard, Margareta Enghag, Linda Schenk, Karim Hamza
6	Radioprotection effects X ionizing radiation	**Cátia Griebler,** Tayana Portela
7	Societal consequences of professional disinformation based on I-131 air concentration: a case study Czech Republic 2017	**Ivana Fojtikova,** Jiri H lka, Michal Jankovec, Karla Petrova
8	What humanitarian lessons of «Chernobyl» should be considered today? Experience of the Republic of Belarus	**Halina Hutsava,** Mikalai Barysevich
9	What role does the professional society play in setting and enforcing ethical standards?	**Nicole Martinez**

ERPW Session 02: **Management of emergency and post-accident situations: how to optimize population evacuation zones and related decision making processes?**

Nº	TITLE	AUTHORS
10	A comparison between three different approaches in defining population evacuation zones in defining a priori emergency plans	**Alessandra Balestreri,** Daniela Lunesu , Maurizio Forte, Emanuela Marangoni, Rosella Rusconi, Maurizio Bassanino
11	Analysis of childhood thyroid cancer incidence in Fukushima based on dose response relationship	**Takahiro Wada,** Hiroshi Toki, Yuichiro Manabe, Toshihiro Higuchi, Masako Bando
12	Analysis of the wind dynamics in estimating the transboundary nuclear accident impact and evaluation of protective countermeasures for the public: case study in Italy	**Giorgia Iurlaro,** Miguel Angel Hernandez-Ceballos, Silvia Scarpato, Luca De Felice, Carlo-Maria Castellani, Ignazio Vilardi, Luciano Sperandio, Giorgia Cinelli, Konstantins Bogucarskis, Marco Sangiorgi, Marc De Cort
13	Dose to individuals as a basis for decision-making in supporting health follow up and resilience of affected population after a nuclear accident: Recommendations from the SHAMISEN project	**Paola Fattibene,** Joan Francesc Barquinero, Sara Della Monaca, Liudmila Liutsko, Keiichi Akahane, Lleonard Barrios, Celine Bassinet, Cecile Challeton-de Vathaire, Vadim Chumak, Didier Franck, Eric Gregoire, Alicja Jaworska, Kenji Kamiya, Atsushi Kumagai, Osamu Kurihara, Ulrike Kulka, Cristina Nuccetelli, Ursula Oestreicher, Takashi Ohba, Marion Peter, Christiane Poelzl-Viol, Koichi Tanigawa, Francois Trompier, Elisabeth Cardis
14	DosiKit, a new portable assay for fast external irradiation biodosimetry	**Julie Etzol,** Sandrine Altmeyer, Caroline Bettencourt, Samuel Bouvet, Louis Boyer, Youenn Corre, Michel Drouet, Fabrice Entine, Benoit Faye, Océane Grand, Joel Guersen, Flora Jourquin, Mathieu Lanaret, Yannick Lecompte, Xavier Michel, Yassine Rizzi, Nicolas Ugolin, Marco Valente, Sylvie Chevillard
15	Evacuation after a nuclear accident: critical reviews of past nuclear accidents and proposal for future planning based on recommendations of the SHAMISEN project	**Takashi Ohba,** Koichi Tanigawa, Liudmila Liutsko, Elisabeth Cardis
16	Four years of dialogue for the rehabilitation of living conditions in the area contaminated by the Fukushima accident	**François Rollinger,** Ryoko Ando, Jacques Lochard, Valérie Marchal
17	Internal contamination in post-accidental situations: a multi-pollution to take into account?	**Jean-Marc Bertho,** Stefania Musilli, Karine Tack
18	Lessons from Chernobyl and prognosis for Fukushima: thyroid cancer incidence	**Viktor Ivanov,** Valerii Kashcheev, Alexandre Menyajlo, Natalia Seleva, Vladimir Saenko, Shunichi Yamashita

ERPW Posters Sessions

Nº	TITLE	AUTHORS
19	Market access of calixarene cleansing nanoemulsion for the treatment of skin contamination by uranium, plutonium ans americium	**Pascal Chanton,** Stéphane Destaing
20	Optimization of employee evacuation procedure during annual emergency exercise in ENEA Casaccia site	**Luciano Sperandio,** Iurlaro Giorgia, Vilardi Ignazio
21	Psychological features of radiation risk perception	**Konstantin Loganovsky,** Marina Gresko
22	Results of a global inter-laboratory comparison on the cytogenetic and genomic assays in the frame of the European Network of Biodosimetry - RENEB	**Eric Grégoire,** Lleonard Barrios, Joan Francesc Barquinero, Christina Beinke, Philip Beukes, Inmaculada Dominguez, Pham Ngoc Duy, S. Filippi, Inci Guclu, Kamile Guogyte, Valeria Hadjidekova, Seongjae Jang, K. Karthick, Liz Ainsbury, Barbara Kutzner, Katalin Lumniczky, Alegria Montoro, Roberta Meschini, Mirta Milic, Octavia Monteiro-Gil, Mercedes Moreno, Ursula Oestreicher, Jelena Pajic, Clarice Patrono, Maria Prieto, Michelle Ricoul, Laurence Roy, Laure Sabatier, Natividad Sebastia, Sylwester Sommer, Georgia Terzoudi, Antonella Testa, Anne Vral, Demetre Zafiropopoulos, Marco Valente, Perumal Venkatachalam, Ruth Wilkins, Andrzej Wojcik, Ulrike Kulka

ERPW Session 03:
Why is radioecology an essential science when analyzing human population exposure?

23	5th European IRPA Congress, 4 - 8 June 2018, The Hague	**Hielke Freerk Boersma,** Gert Jonkers, Bert Gerritsen, Carel Thijssen, Jan Kops, Lars Roobol, Ronald Smetsers
24	Incorporating radioecology in an interdisciplinary approach to education and research: the Center for Nuclear Environmental Engineering Sciences and Radioactive Waste Management at Clemson University	**Nicole Martinez,** Timothy DeVol, Lindsay Shuller-Nickles, Brian Powell
25	Present status of radioecological condition in Indonesia marine water	**Heny Suseno,** Ikhsan B Wahono
26	Radionuclide transport in snow - Combined study of laboratory tracer experiments and field work on Mt. Zugspitze, Germany	**Kerstin Hürkamp,** Jochen Tschiersch

ERPW Session 04:
Benefit vs risk in diagnostic and interventional radiology

27	National variation in pediatric non-contrast head CT radiation dose indices	**Gelareh Sadigh,** Nadja Kadom, Donald Frush, Mythreyi Chatfield, Debapriya Sengupta, Karthik Priyadrashini, Keith Straus, Kimberly Applegate
28	Analysis of trend of conventional radiography usages in Korea	**Jai Ki Lee,** Kwang Pyo Kim, Young Khi Lim, Ji Young Song
29	Calculation of radiation dose in adults undergoing abdomen and pelvis CT examination	**Jai Ki Lee,** Kwang Pyo Kim, Il Park, Yongin Ji
30	Cerebrocortical knockdown of p53 partially rescues radiation-induced microcephaly in mice	**André Claude Mbouombouo Mfossa,** Mieke Verslegers, Sarah Baatout, Mohammed Abderrafi Benotmane, Danny Huylebroeck, Roel Quintens
31	Development of methodology and software to assess long-term health risks after breast cancer therapy and heart diagnostic procedures (PASSOS)	**Markus Eidemueller**
32	EMT is driven by low-dose irradiation in keratinocyte precursor cells during human epidermis generation	**Michele Martin,** Sophie Cavallero, Nicolas Fortunel, Daniel Stockholm
33	Evaluation of radiation-dose reduction with new micro-dose protocol; first phantom measurements of organ dose and effective dose with the EOS® micro-dose protocol in full-spine examinations	**Peter Heide Pedersen,** Asger Greval, Svend Erik Ostgaard, Torben Tvedebrink, Søren Peter Eiskjær
34	Hyperthermia combined with radiotherapy: ongoing in vitro studies at ENEA laboratories	**Antonella Testa,** Maria Balduzzi, Clarice Patrono, Vanni Lopresto, Giorgio Leter, Valentina Palma, Carmela Marino
35	Identification of risk aversion factor for radiation workers in the Republic of Korea	**Abdulbagi Fadul,** Seong Na

Nº	TITLE	AUTHORS
36	Peripheral organ doses and secondary cancer risks in tangential and multi-field breast cancer radiotherapy	**Cristoforo Simonetto,** Hannes Rennau, Julia Remmele, Pavel Kundrat, Markus Eidemueller, Ulrich Wolf, Guido Hildebrandt
37	Prospectivity of NOS inhibitors application as hypoxic radioprotectors in nuclear medicine	**Marina Filimonova,** Alina Samsonova, Victoria Makarchuk, Ekaterina Chesnakova, Tatiana Korneeva, Ljudmila Shevchenko, Stephan Ulyanenko, Alexander Filimonov
38	Radiation dose optimization and risk estimation to pediatrics during micturition cystourethrography	**Edrees Mhamad Nury**
39	The radiation dose monitor® dose archiving and communication system: a tool for patients' risk management in interventional radiology	**Jad Farah,** Marie Josephine Waryn, Lama Hadid-Beurrier, Antonella Jean-Pierre, Patricia Pierre, Bouchra Habib Geryes
40	The role of intercellular communication in endothelial cell response after ionizing radiation exposure	**Raghda Ramadan,** Els Vromans, Elke Decrock, luc Leybaert, Sarah Baatout, An Aerts
41	What is the impact of iodinated contrast media on the radiation doses from diagnostic x-ray examinations?	**Elizabeth Ainsbury,** Richard Harbron, Mark Pearce, Simon Bouffler, Rick Tanner, Jonathan Eakins
42	Workflow-quality control in mammography practices using a dose management software tool	**Timo de Bondt,** Federica Zanca, Mireille Van Goethem, Inge Verslegers, Lieve Hufkens, Astrid Van Hoyweghen, Paul Parizel

ERPW Session 05:
Medical radiation incidents/accidents

43	Radiotherapy-induced phenotypical changes in peripheral blood mononuclear cells of head and neck cancer patients	**Katalin Lumniczky,** Katalin Balázs, Enik Kis, Tünde Szatmári, Enik Noémi Bogdándi, Géza Sáfrány, Piotr Widlak

ERPW Session 06:
Internal dosimetry

44	A method of in vitro dissolution test for enhanced reliability of internal radiation dose assessment	**Ji-Yong Shin,** Kim Eun-Hee
45	A new approach to counting measurements: addressing the problems with ISO-11929	**John Klumpp,** Deepesh Poudel
46	A simple test to assess radionuclide bioavailibility and efficacy of chelating drugs	**Anne Van der Meeren,** Nina Griffiths
47	Alpha emitters in nuclear medicine: from the physical dose to the biological effects in non-target tissues	**Antonella Testa,** Valentina Palma, Clarice Patrono
48	Analysis of 6 Cf252 cases	**Richard Bull,** Gareth Roberts
49	Challenges for operational occupational internal dosimetry - the need to develop methods and obtain additional data for committed dose assessments due to fundamental changes in the ICRP recommendations	**Christopher Rääf,** Anja Almén
50	Contribution of internal dose to the exposure in the Fukushima exclusion zone	**Jochen Tschiersch,** Kazuya Yoshimura, Vladimir Spielmann, Kazuki Iijima, Taeko Shinonaga, Kaname Miyahara
51	Development and application of a statistical tool to analyze biodistribution data from internal contamination	**Stephanie Lamart,** Anne Van der Meeren, Solveig Bibard, Jaime F Angulo, Nina M Griffiths
52	Dose coefficients in nuclear nephrology paediatric patients and dose assessment. Age or body weight?	**Pedro Teles,** Jéssica Costa, Durval Costa
53	Establishment of detailed respiratory tract model and the Monte Carlo simulation of radon progeny caused dose	**Hongyu Zhu,** Rui Qiu, Yuxi Pan, Zhen Wu, Chunyan Li, Junli Li
54	Estimation of thyroid equivalent dose at 1 year-old children by inhalation including short half-life radionuclides based on body surface contamination level after the Fukushima Daiichi nuclear power plant accident	**Takashi Ohba,** Arifumi Hasegawa, Gen Suzuki
55	Evaluating image degradation influence on calibration factor estimation in quantitative Lu-177-PSMA SPECT	**Elham Karimi Ghodoosi,** Calogero D'Alessandria, Ye Li, Michael Ghaly, Nassir Navab, Weibo Li, Eric Frey, Sibylle Ziegler
56	Measurements of iodine activity in thyroid after medical administration	**Jakub O ko,** Renata Sosnowiec, Tomasz Pliszczy ski

ERPW Posters Sessions

Nº	TITLE	AUTHORS
57	Numerical computation of internal radon doses for home and mine environments	**Ágnes Jókay,** Árpád Farkas, Péter Füri, Balázs Gergely Madas, Emese Drozsdik, Imre Balásházy
58	Patient specific voxelized nuclear medicine internal dose estimation based on SPECT/CT imaging	**Ruiyao Ma,** Rui Qiu, Junli Li, Li Ren, Zhen Wu, Chunyan Li
59	Smart technology for indoor radon measurement and dose estimation	**Jiri H lka,** Ivana Fojtikova, Ales Fronka, Karel Jilek
60	Uncertainty and variance-based sensitivity analysis of organ dose estimates in nuclear medicine	**Alexandra Zvereva,** Florian Kamp, Helmut Schlattl, Maria Zankl, Augusto Giussani, Katia Parodi

ERPW Session 07:
What are the evidences for trans/multigenerational radiation-induced effects and are they of concern?

61	Blood system parameters of the first generation offspring of laboratory rats exposed to 131I	**Alla Lypska,** Natalia Riabchenko, Olena Ganzha, Yevgenia Prokhorova, Victoria Talko

ERPW Session 08:
Biomarkers and cohorts suitable for exploring low-dose/low-dose-rate exposure effects and individual susceptibility (humans, animals and plants)

62	A mathematical model to evaluate radiation-related biological effects - toward a unified and quantitative understanding	**Yuichiro Manabe,** Takahiro Wada, Masako Bando
63	A new mouse model to underpin the application of a DDREF to improve estimated leukaemia risk at low doses/dose rates in humans	**Natalie Brown,** Rosemary Finnon, Paul Finnon, Ann-Karin Olsen, Dag Eide, Christophe Badie
64	Assessing the linearity of dose responses for the risk of lung squamous cell carcinoma caused by different radiation fields	**Noemi Castelletti,** J. Christian Kaiser, Lydia B. Zablotska, Georgios T. Stathopoulos, Kyoji Furukawa, Helmut Küchenhoff
65	Assessment of circulating endothelial cells in interventional cardiac catheterization laboratory staff exposed to low dose of X-radiation	**Fadi Najjar,** Ghassan Al Massarani, Majed Othman
66	Background radiation-induced differences of Copy Number Variations between radiosensitive and regular response patients	**Joanna Tobiasz,** Ghazi Alsbeih, Joanna Polanska
67	Cancer risk and occupational radiation exposure among medical radiation workers: results from national dose registry in Korea	**Seulki Ko,** Won Jin Lee, Eun Shil Cha, Yeongchull Choi
68	Chromosome aberrations and DNA damage in peripheral blood lymphocytes of patients undergoing radiotherapy: Initial results from the RTGene study	**Jayne Moquet,** Navita Somaiah, Christophe Badie, Stephen Barnard, Sue Boyle, Clare Bricknell, Lourdes Cruz-Garcia, Ellen Donovan, Lone Gothard, Manuel Higueras, Grainne Manning, Mingzhu Sun, Elizabeth Ainsbury
69	Dose-rate effects on cancer mortality risk estimates for Japanese nuclear workers	**Hiroshige Furuta,** Shin'ichi Kudo, Jun'ichi Ishida, Keiko Yoshimoto, Fumiyoshi Kasagi
70	Dosimetric and neuropsychiatric issues of hippocampal irradiation in interventional radiologists	**Konstantin Loganovsky,** Tatiana Loganovska, Donatella Marazziti, Vadim Chumak, Federico Mucci, Artem Morgun, Olena Bakhanova, Konstantin Kuts
71	Effects of gamma radiation on reproductive parameters in male mice exposed to different doses and dose rates at different stages of gametogenesis	**Dag M. Eide,** Ann Karin Olsen, Hildegunn Dahl, Anne Graupner
72	Epidemiological research in French cohorts of uranium workers for exploring low-dose and low-dose-rate exposure effects	**Olivier Laurent,** Eric Samson, Estelle Davesne, Ségolène Bouet, Eric Blanchardon, Sophie Ancelet, Iris Jovanovic, Cécile Challeton de Vathaire, Dominique Laurier
73	Event-related potentials as a psychophysiological detector of brain damage following radiation exposure in a low-dose range	**Konstantin Loganovsky,** Konstantin Kuts
74	Flowcytometric analysis of microparticle phenotypes in occupational workers exposed to low doses of ionizing radiation	**Ghassan Al Massarani,** Fadi Najjar, Adnan Ikhtiar
75	Functional gene analysis reveals cell cycle changes and inflammation in endothelial cells irradiated with a single X-ray dose	**Bjorn Baselet,** An Aerts, Sarah Baatout, Pierre Sonveaux

Nº	TITLE	AUTHORS
76	Genetic factors in radiation-induced gamma-H2AX phosphorylation and in silico based identification of SNPs influencing its response level	**Joanna Zyla,** Sylwia Kabacik, Grainne Manning, Paul Finnon, Salma Wakil, Ghazi Alsbeih, Christophe Badie, Joanna Polanska
77	Genotoxicity of different low dose rates of gamma radiation in three strains of mice	**Ann-Karin Olsen,** Dag M. Eide, Christophe Badie, Simon Bouffler, Dag A. Brede, Brit Saibu, Deborah H. Oughton, Anne Graupner
78	Heterogeneity of dose-response at low dose level in the life span study of atomic bomb survivors	**Kotaro Ozasa**
79	High dose irradiation induces metabolic reprogramming in endothelial cells	**Bjorn Baselet,** An Aerts, Sarah Baatout, Pierre Sonveaux
80	How structural changes in genome are connected with radiosensitivity level? Copy number variation analysis	**Bożena Rolnik,** Joanna Polanska, Ghazi Alsbeih
81	HTO and tritiated amino acid exposure induces differential effects on haematopoiesis and iron metabolism	**Jean-Marc Bertho,** Dimitri Kereselidze, Line Manens, Cécile Culeux, Joel Surette, Melinda Blimke, Lindsey Bertrand, Heather Wyatt, Maamar Souidi, Nick Priest, Jean-René Jourdain
82	Impact of 131I prenatal exposure on brain: experimental model of clinical neuroradioembriological effects	**Victoria Talko,** Konstantin Loganovsky, Yeugenij Tukalenko, Tatiana Loganovskaja, Stanislav Nechayev, Sergij Masyuk, konstantin Kuts, Yeugenia Prokhorova, Oxana Boyko
83	Low dose external Ð ionizing radiation regulates mouse immune cells in a dose and dose-rate- dependent manner	**Teni Ebrahimian,** Christelle Demarmquay, Talin Ebrahimian, Juliana Vieira-Dias, Dimitri Kereselidze, Celine Gloaguen, Alice Bontemps, Gunilla Olson, Siamak Haghdoost, Karine Tack
84	Low doses of gamma irradiation enhance the efficiency of DNA repair in Drosophila melanogaster	**Giovanni Cenci,** Francesca Cipressa, Antonella Porrazzo, Patrizia Morciano, Giuseppe Esposito, Luigi Satta, Maria Antonella Tabocchini
85	Molecular-cerebral biomarkers of low doses of ionizing radiation	**Dimitry Bazyka,** Konstantin Loganovsky
86	Multicenter CT protocols harmonization according to clinical indication and anatomical region for DRLs comparison: intermediate results of a prospective study	**Hugues Brat,** Federica Zanca, Sima Imsand, Stéphane Montandon, Damien Racine, Cyril Thouly, Christophe Dias, Hugo Pasquier, Eric Meicher, Dominique Fournier
87	NASA space radiation health Risks (Cancer, Cognition, Cardiovascular) and potential common pathways	**Zarana Patel,** Janice Huff, Greg Nelson, Lisa Simonsen
88	Radiation risk estimates adjusted for smoking in a Japanese nuclear worker cohort	**Shin'ichi Kudo,** Jun'ichi Ishida, Keiko Yoshimoto, Sumio Ohshima, Hiroshige Furuta, Fumiyoshi Kasagi
89	Radiation risk of incident colorectal cancer by anatomical site among atomic bomb survivors: 1958-2009	**Hiromi Sugiyama,** Munechika Misumi, Eric Grant, Ritsu Sakata, Atsuko Sadakane, Mai Utada, Dale Preston, Kiyohiko Mabuchi, Kotaro Ozasa
90	Regression analysis for dose and age related deregulated proteins	**Anna Papiez,** Omid Azimzadeh, Soile Tapio, Joanna Polanska
91	Study design and baseline findings of cross-sectional study among interventional medical workers in Korea	**Ye Jin Bang,** Won Jin Lee, Seulki Ko, Yae Won Ha, Hwan Hoon Chung, Sung Bum Cho, Young Woo Jin, Kwang Pyo Kim, Ha Ha
92	Urothelial cancer incidence among the life span study of atomic bomb survivors: 1958 to 2009	**Jaeyoung Kim,** Kotaro Ozasa, Dale Preston, Kiyohiko Mabuchi, Hiromi Sugiyama, Atsuko Sadakane, Ritsu Sakata, Eric Grant

ERPW Session 09:
Use of observatory sites for integrated long-term research activities

93	Low dose radiation research organized by adverse outcome pathway model	**Donald Cool,** Phung Tran, Lawrence Dauer
94	Spatial datasets of radionuclide contamination in the Ukrainian Chernobyl exclusion zone	**Nicholas Beresford,** Jacky Chaplow, Valeriy Kashparov, Slava Levchuk, Marina Zhurba
95	The fen complex - a potential Norwegian NORM observatory site	**Alicja Jaworska,** Runhild Gjelsvik, Hallvard Haanes, Sven Dahlgren, Ingvild Engen Finne, Emmanuel Lapied, Line Nybakken, Lindis Skipperud, Hilde Kristin Skjerdal, Christian Bianchi Stromme, Anne Liv Rudjord

Nº	TITLE	AUTHORS

ERPW Session 11:
Radioactive iodine: gaps and knowledge needed for nuclear crisis integrated management

Nº	TITLE	AUTHORS
96	For a better understanding of iodine reactivity/transport in the troposphere	**Florent Louis,** Valérie Fevre-Nollet, Frédéric Cousin, Anne-Cécile Grégoire, Denis Maro
97	Main progresses in the iodine source term assessment since 90's	**Anne-Cécile Grégoire,** Loic Bosland Laurent Cantrel, Juliette Colombani, Anne Mathieu, Olivier Saunier, Christian Mun, Frédéric Cousin
98	Medical I-131: usage and appearance in the environment	**Volker Hormann,** Maria Evangelia Souti, Helmut W. Fischer
99	Results of a European intercomparison on the measurement of I-131 in thyroid	**Anne Laure Lebacq,** Masa Takahashi, Mats Isaksson, Mirela Saizu, Isabelle Vu, David Broggio
100	Thyroid monitoring with non-spectrometric instruments - Results from an intercomparison exercise within the OPERRA/CAThyMARA project	**Mats Isaksson,** David Broggio, Pavel Fojtik, Anne Laure Lebacq, Juan Francisco Navarro Amaro, Jakub Osko, Begona Perez Lopez, Isabelle Vu

ERPW Session 12:
Dosimetry in complex fields

Nº	TITLE	AUTHORS
101	A new smart triage mode biodosimetry assay combining three different techniques	**Antonella Testa,** Valentina Palma, Clarice Patrono
102	An active spherical neutron spectrometer for workplace monitoring in complex fields	**Jose M. Gomez-Ros,** Roberto Bedogni, Davide Bortot, Montserrat Moraleda, Andrea Pola
103	Calculation of dose rate for alpha particle irradiation on cultured cell layer	**Ki-Man Lee,** Gwang-Min Sun, Eun-Hee Kim
104	Computation of organ and effective dose coefficients for adult reference phantoms in articulated positions	**Shaheen Dewji,** Eli Sanchez, Kathryn Bales, Mullin Green, K. Lisa Reed
105	Dose trends in occupational radiation exposure among Korean radiation workers in South Korea	**Songwon Seo,** Young Woo Jin, Dal Nim Lee, Jung Un Kim, Sunhoo Park
106	Evaluation of radiation dose rates using the flux to dose conversion factors recommended in ICRP-74 and ICRP-116	**Sy Minh Tuan Hoang,** Thi Thanh Thao Pham
107	External dose coefficients for age-dependent exposures to radionuclides in soil, air, and water	**Shaheen Dewji,** Ken Veinot, Michael Bellamy, Mauritius Hiller, Keith Eckerman, Clay Easterly, Nolan Hertel, Ryan Manger
108	Gamma and neutron dosimetry with hybrid semiconductor pixel detectors	**Peter Rubovi ,** Benedikt Bergmann, Daniela Ekendahl, Ji í H lka, Ivan Štekl
109	Metrology needs related to biological radiation effects	**Hans Rabus,** Woon Yong Baek, Volker Dangendorf, Marion Bug, Ulrich Giese
110	Prostheses in radiodiagnostic and radiotherapy: dose calculation challenges	**Carmine Zicari,** Claudio Andenna, Donatella Sacco, Lidia Strigari, Valeria Landoni, Antonella Soriani
111	Radiation dose rate assessment around radioactive patients in PET/CT units	**Maged Elsaadony,** Randa Mahmoud
112	Radiological Impact of 137Cs by decapods in contribution of Jakarta Bay Physical characteristics	**Wahyu Prihatiningsih,** Nur Yahya
113	Tumor dosimetry for radioimmunotherapy in mouse model using clinical gamma camera imaging with pinhole collimator	**Young Sub Lee,** Min Chul Song, Park Sang Hyun, Min Kyung Kiim, Hyun Suk Yoon, Hwe In Kim, Jaeho Lee, Jae Kwon Jang, Jin Su Kim

ERPW Session 13:
Eye lens exposure and monitoring

Nº	TITLE	AUTHORS
114	LDLensRad: role of miRNAs in radio-induced cataractogenesis	**Mariateresa Mancuso,** De Stefano Ilaria, Tanno Barbara, Babini Gabriele, Leonardi Simona, Giardullo Paola, Pasquali Emanuela, Pazzaglia Simonetta, Saran Anna
115	Radiation-induced DNA damage response in the eye lens	**Michele Ellender,** Hodan Warsama, Sophie A. Lloyd, Stephen G.R. Barnard, Elizabeth A. Ainsbury

Nº	TITLE	AUTHORS
116	Retrospective estimation of the eye lens doses for Greek interventional cardiologists	**Panagiotis Askounis,** Georgios Kyranos, Charicleia Kyrgiakou, Eleni Papadomarkaki, Marilena Roussou, Zoi Thrapsanioti, Eleftheria Carinou
117	Risk of cataract incidence in a cohort of Mayak PA workers following chronic occupational radiation exposure	**Tamara Azizova,** Evgeny Bragin, Nobuyuki Hamada, Maria Bannikova

ERPW Session 14:
Individualized approaches for radiation protection

118	Assessment of the public dose under unusual circumstances of radiation exposure through commodities	**Wanook Ji,** Eun-Hee Kim
119	Deformation of mesh-type ICRP reference computational phantoms for individualized dose calculations	**Yeon Soo Yeom,** Chan Hyeong Kim, Thang Tat Nguyen, Min Cheol Han, Chansoo Choi, Hanjin Lee, Haegin Han, Bangho Shin, Beom Sun Chung
120	Development of mesh-type Chinese pediatric reference phantoms series	**Ruiyao Ma,** Rui Qiu, Junli Li, Li Ren, Zhen Wu, Chunyan Li
121	Evaluation of radiation-induced risk of patients: the EVARISTE project	**Clément Devic,** Mélodie Munier, Nicolas Foray
122	High PATCHED1 protein deficiency in cancer-prone Gorlin patient cells results in cellular radiosensitivity	**Michele Martin,** Adeline Vulin, Melissa Sedkaoui, Pascal Soularue
123	Monte Carlo dosimetry software for patient and medical staff in interventional radiology	**Thomas Deschler,** Sara Beilla, Nicolas Arbor, Pierre Dillenseger, Fanny Carbillet, Abdel-Mjid Nourreddine
124	Multicentre analysis of radiology exposures: the statistics of concern	**Lidion Sibanda,** Penelope Engel-Hills, Egbert Hering, Godfree Azangwe
125	Multidepartment approach for designing a PET/CT Facility: implementation and optimization in a cancer research facility in India	**Ashish Jha,** Sneha Mithun, Ameya Puranik, Manoj Chauhan, Nilendu Purandare, Sneha Shah, Archi Agrawal, Venkatesh Rangarajan
126	New IAEA coordinated research project: applications of biological dosimetry methods in radiation oncology for improvement of radiation safety of patients - towards individualised medicine	**Oleg Belyakov,** Eduardo Zubizarreta
127	OpenRadiation: a collaborative project for radioactivity measurements in the environment by the public	**Jean-François Bottollier-Depois**
128	ProZES: a German tool for evaluating probability of cancer causation due to radiation exposure	**Alexander Ulanowski,** Denise Guethlin, Peter Jacob, Jan Christian Kaiser, Elena Shemiakina, Markus Eidemueller
129	Radiation-induced chromosome aberrations in Human lymphocytes as biomarkers for individual radiosensitivity assessment	**Nathalia Riabchenko**
130	Study of naturally occurring radioactive material (NORM) in water supply treatment plants	**Kanpirom Yangsup,** Naowarut Charoenca, Piyawan Krisanangkura, Nipapun Kungskulniti
131	Study on radiation dose and shielding effect in maintenance of proton accelerator for radiation therapy	**Sanghoon Lee,** Jeongmun Son, Wonrak Jung, Wangshin Hwang, Sungil Cho, Sanghun Hyun, Hyungjun Kong, Jaeseok Yang, Dongho Shin
132	The combined effect of alpha particles and cigarette smoke on human lung epithelial cells in terms of DNA double strand breakage induction	**Ui-Seob Lee,** Eun-Hee Kim

ERPW Session Miscellaneous

133	A plan of new network for low dose radiation research in Japan: PLANET	**Yamada Yutaka,** Yoshiya Shimada, Michiya Sasaki, Tetsuo Nakajima, Mayumi Nishimura, Takamitsu Morioka, Kazuhiro Daino, Tatsuhiko Imaoka, Shizuko Kakinuma
134	Association between serotonin transporter polymorphisms (5-HTTLPR and rs25531) and depression in clean up workers in remote period of Chornobyl accident	**Konstantin Loganovsky,** Stanislav Chumak, Iryna Abramenko, Nadiia Bilous
135	Bridging the gap between radiobiology and medical use of ionizing radiation - JSPS committee «multidisciplinary research on biological effects of radiation»-	**Takahiro Wada,** Yuichiro Manabe, Masako Bando, Yoshiharu Yonekura
136	CEFRI, Your radiation protection certification body	**Pascal Vaucheret,** Michel Fondeviole

ERPW Posters sessions

Nº	TITLE	AUTHORS
137	COMET - Coordination and implementation of a pan-european instrument for radioecology	**Hildegarde Vandenhove**
138	Current activities of EUTERP, the European Training and Education in Radiation Protection Foundation	**Penelope Allisy,** Michèle Coeck, Folkert Draaisma, Friedrich Hoyler, Richard Paynter, Marcel Schouwenburg, Joanne Stewart
139	Development of off-site radiological consequence assessment model	**Juyub Kim,** Youngsuk Bang, Seungwon Seo, Songjae Yoo
140	Dispositif de radioprotection et la surveillance médicale du personnel exposé aux rayonnements ionisants : état des lieux dans un CHU du centre d'Alger	**Amina Rezak,** Tarik Melzi, Amina Mahdi, Hayette Benmessaoud
141	Education and training in radiological protection by the SCKÐCEN Academy	**Tom Clarijs,** Michèle Coeck
142	From DDREF to EDR - What the history of LNT indicates	**Masako Bando,** Takahiro Wada, Yuichiro Manabe
143	Health hazards effects due to exposure of radon, thoron and progeny in normal and high background radiation areas	**Rakesh Chand Ramola**
144	Hybrid gold nanoparticles coated with organic polymers and antibodies as a platform for cancer theranostics: Cytotoxicity assessment	**Noami Daems,** Sha Li, Ornella Fichera, Karen Van Hoecke, Sarah Baatout, Thomas Cardinaels, Carine Michiels, Stéphane Lucas, An Aerts
145	Lessons learned from the ETRAP2017 International Conference on Education and Training in radiation protection	**Michèle Coeck,** Richard Paynter, Penelope Allisy-Roberts
146	Lifetime attributable risk of cancers due to occupational radiation exposure among medical workers in Korea	**Yeongchull Choi,** Won Jin Lee, Jaeyoung Kim, Eun Shil Cha
147	MEDIRAD - Implications of medical low dose radiation exposure	**Elisabeth Cardis,** Guy Frija
148	Monte Carlo simulation and experimental measurement for CT dosimetry	**Pierre Gillet,** Mélodie Munier, Fanny Carbillet, Nicolas Arbor, Ziad El Bitar
149	PARISII: internal contamination facility for rodents	**Roy Laurence,** Karine Tack, Delphine Denais Laliève, Isabelle Dublineau, Eric Vial, Stéphane Grison, Michael Brassart, Laurent Tillault, Marc Benderitter
150	Radiation induced damages of The Bronchopulmonary system in the cleanup workers of the Chernobyl NPP Accident (1988-2016)	**Viktor Sushko,** Kostjantin Bazyka, Alorna Rjazska
151	Radiation protection and health of personnel of contractor enterprises which participate in «shelter implementation project»	**Viktor Sushko,** Lyudmila Lyashenko, Olena Kolosynska
152	Radiation protection strategic research needs in the United States	**Shaheen Dewji,** Nolan Hertel
153	Research trends of biological effects on low dose radiation: after four decades of the Chernobyl nuclear accident	**Taewoo Kwon,** Young Woo Jin, Ki Moon Seoung, Sunhoo Park, Seung-Sook Lee
154	Similarities and differences between human and wildlife dosimetry: a brief overview	**Karine Beaugelin-Seiller,** Eric Blanchardon
155	The STORE database; sharing data and bioresources in radiobiology	**Paul Schofield,** Michael Gruenberger, Mandy Birschwilks, Clemens A delmann, Soile Tapio, Gayle Woloschak, Shin Saigusa, Nicholas Beresford, Bernd Grosche, Ulrike Kulka
156	Towards the development of the joint and individual roadmaps for radiation protection research	**Nathalie Impens**

Exhibitor Information

Booth **1** **MEDSQUARE**

17 rue du Jura 75013 Paris France

http://www.medsquare.com/en/

Medsquare is a leading player in the DACS (Dose Archiving and Communication System) market.

Our Radiation Dose Monitor - RDM - is a multi-modality software solution that helps healthcare organizations optimize radiation dose and clinical practices. Recognized as the most complete DACS on the market, RDM fully supports compliance with the impending European Directive 2013/59/Euratom. Today, the solution is connected to 500 equipment and tracks more than 3 million patients over the world.

After winning the majority of public tenders in France (UniHA, Resah, AP-HP), Medsquare has stepped up to the pan-European level and is positioned ahead of all local and international competitors. Manufacturers also selected Medsquare for its DACS RDM solution under their different tenders awarded. These collaborations further extends Medsquare's roots in France and Europe, where the company continues to develop large-scale projects.

Booth **2** **NEOLYS DIAGNOSTICS**

Centre Léon Bérard Bât. Cheney A - 28 rue Laennec 69373 Lyon Cedex 08 France

http://www.neolysdiagnostics.com/en/

Neolys Diagnostics - From radiobiology to real life solution for patient and clinicians

Dedicated to bringing precision medicine in radiotherapy, Neolys Diagnostics develops innovative and efficient products to improve patients' outcome and treatments, based in Lyon (France). It proposes efficient solutions for decision-making to radiation oncologists, allowing them to adapt treatment as per radiosensitivity of individual patients. This helps in reducing side effects while optimising the treatment efficacy.

This disruptive innovation relies on individual radiosensitivity researches carried out by the Radiobiology Group of the CRCL (UMR1052, Lyon - France).

Booth **3** *et* **4** **Institut de Radioprotection et de Sûreté Nucléaire**

31 Avenue de la Division Leclerc 92260 Fontenay-aux-Roses France

http://dosimetre.irsn.fr/fr-fr

IRSN Dosimetry Lab has been the French national reference for more than 50 years for occupational dosimetry service.

Yesterday, IRSN chose the RPL technology and invested in a high capacity and high technology facility available to take more than 10 000 radiation measurements a day.

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IRSN Dosimetry Lab also offers devices for extremity and eye lens dosimetry easy to implement.

Booth **5** Chiyoda Technol Corporation

1-7-12, Yushima, Ochanomizu, Bunkyo-ku 113-8681 Tokyo Japan

www.c-technol.co.jp

Pioneer in radiation protection in Japan and RPL dosimetry system in the World.

We have been performing the dosimetry service to ensure the safety of the various operators in the field of radiation since 1954. Today, more than 300 000 workers use our RPL Glass Badge dosimeters in Japan.

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- D-Shuttle, the electronic dosimeters for daily radiation measurement, developed for and used by people living in the Fukushima area.

- TechnoTrack, high quality PADC plastic for neutron detection, and its Reader. We succeeded in drastically reducing the false pits.

Booth **6** CEVIDRA

Laboratoire CEVIDRA 45 Bd Marcel Pagnol 06130 Grasse France

www.cevidra.com

CEVIDRA Makes available irsn patented calixarene cleansing nanoemulsion for skin contamination by uranium and plutonium and starts research to extend usage to activation products.

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Booth **7** EUTERP - INSTN - SCK•CEN

EUTERP - European Training and Education in Radiation Protection Foundation

Stichting EUTERP Westerduinweg 3 1755 Le Petten The Netherlands

www.euterp.eu

The European Training and Education in Radiation Protection Foundation (EUTERP) encourages and supports harmonization of education and training requirements for RPEs, RPOs and radiation workers, facilitating the mobility of these professionals.

It promotes the integration of radiation protection education and training systems into general vocational training and education infrastructures and acts as a central focus for the sharing of information on training events, standards, developments, and all other related information.

SCK•CEN - Belgian Nuclear Research Centre

Boeretang 200 2400 Mol Belgium

www.sckcen.be

Within the SCK•CEN Academy, more than 60 years of nuclear expertise and experience gained from our different research projects is collected and transferred.

In the interests of maintaining a competent workforce in industry, healthcare, research, and policy, and of transferring nuclear knowledge to the next generations, the SCK•CEN Academy takes it as its mission to (i) provide guidance for young researchers, (ii) organise academic courses and customised training for professionals, (iii) offer policy support with regard to education and training matters and (iv) care for critical-intellectual capacities for society.

INSTN - Institut national des sciences et techniques nucléaires

Centre CEA 91191 Gif-sur-Yvette France

http://www-instn.cea.fr/en/

The INSTN, Institut national des sciences et techniques nucléaires (National Institute for Nuclear Science and Technology)

Is a public higher education institution administered by the CEA (French Atomic Energy and Alternative Energies Commission) under the joint authority of the Ministry of National Education, Higher Education and Research, the Ministry of the Economy, Industry and the Digital Sector and the Ministry of the Environment, Energy and Marine Affairs.

Booth **8 SAGE Publishing**

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Booth **9 ICRP 2019**

www.icrp2019.com

ICRP is heading to Australian in 2019

The Australasian Radiation Protection Society (ARPS) and Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) would like to invite you to the 5th International Symposium on the System of Radiological Protection in Australia in 2019.

From the 19 – 23 November 2019 the Symposium will take place in Adelaide, the vibrant capital city of South Australia.

The opportunity to meet and discuss radiation safety matters in all areas of application of ionizing and non-ionizing radiation.

Radiation safety professionals face continuing challenges with evolving standards, increased proliferation of complex radiation technologies, such as medical sector radiation applications, in an environment of tight resources and increased regulatory scrutiny.

The 2019 Symposium will offer the opportunity for face to face discussion in all areas of our profession and a packed social program will also allow the opportunity see some sights, sample wine and produce from one of Australia's best regions.

General Information

The 4th International Symposium on the System of Radiological Protection and 2nd European Radiological Protection Research Week will be held at the Disney Newport Bay Club Convention Centre.

Access

By Air

- From Roissy-Charles de Gaulle airport: TGV link in 10 minutes, 45-min ride with direct shuttle bus
- From Orly airport: 45-min ride with direct shuttle bus

By train

The "Marne-la-Vallée/Chessy" railway station is located at Disney's main entrance

- RER: 50 minutes from the centre of Paris with line A (red line)*.
- TGV, Thalys, Eurostar: direct access to the railway station departing from more than 30 cities in France and in Europe*.

** from the exit way, turn left, through the security gate and cross over the Disney village, then go along the lake to the Newport Bay Club Hotel, 10-12 minutes' walk. Or take the free shuttle (white shuttle), 10-12 minutes'drive (stop to the different hotels).*

By car

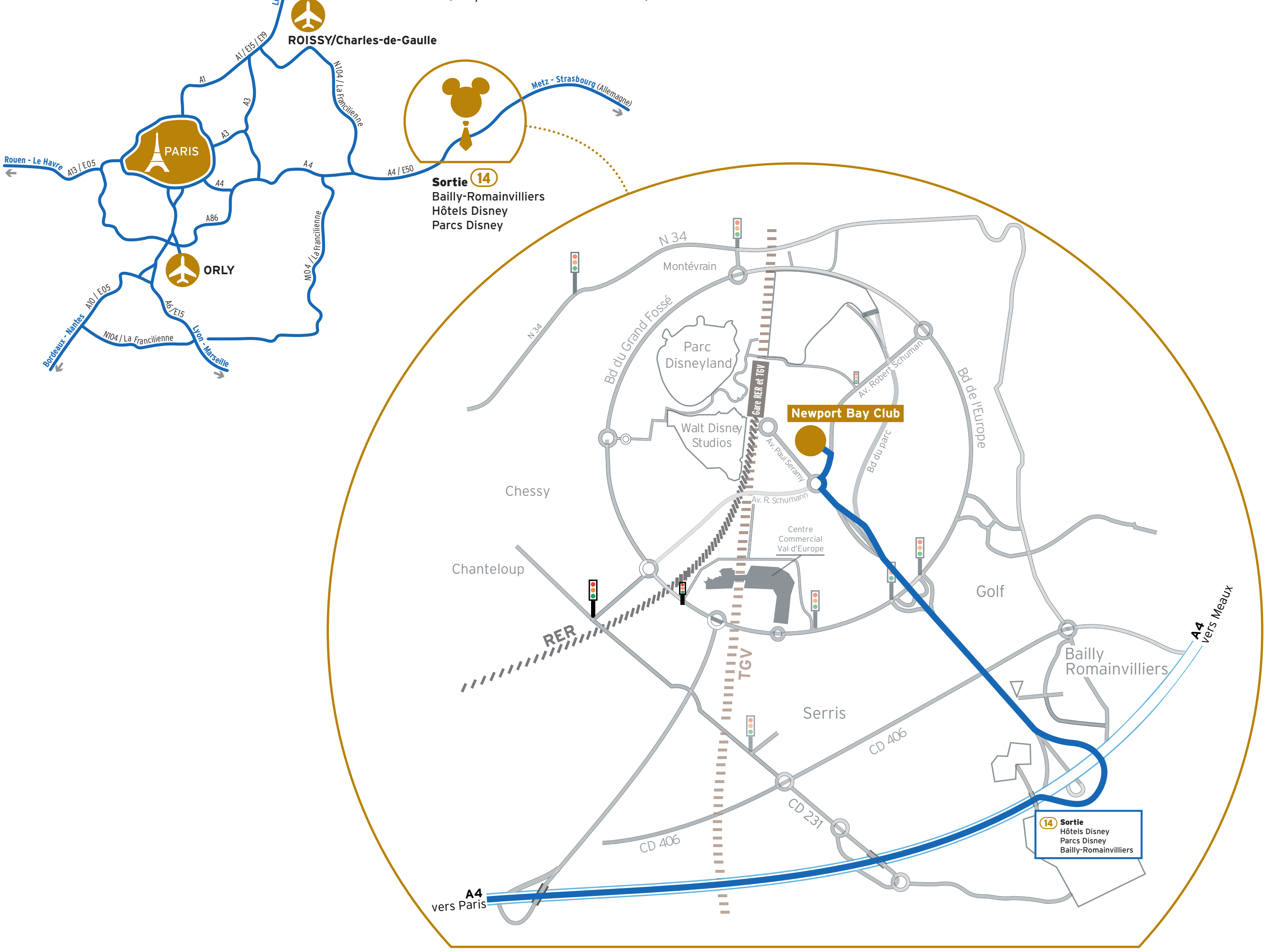
A4 motorway (exit 14), 45 minutes journey from Paris

Taxis

Taxis can drive you to Disneyland Paris from the airports or from the centre of Paris

- Centre of Paris: 55 € to 70 €**
- Roissy-Charles de Gaulle airport: 80 €**
- Orly airport: 85 €**

*** Approximatively*

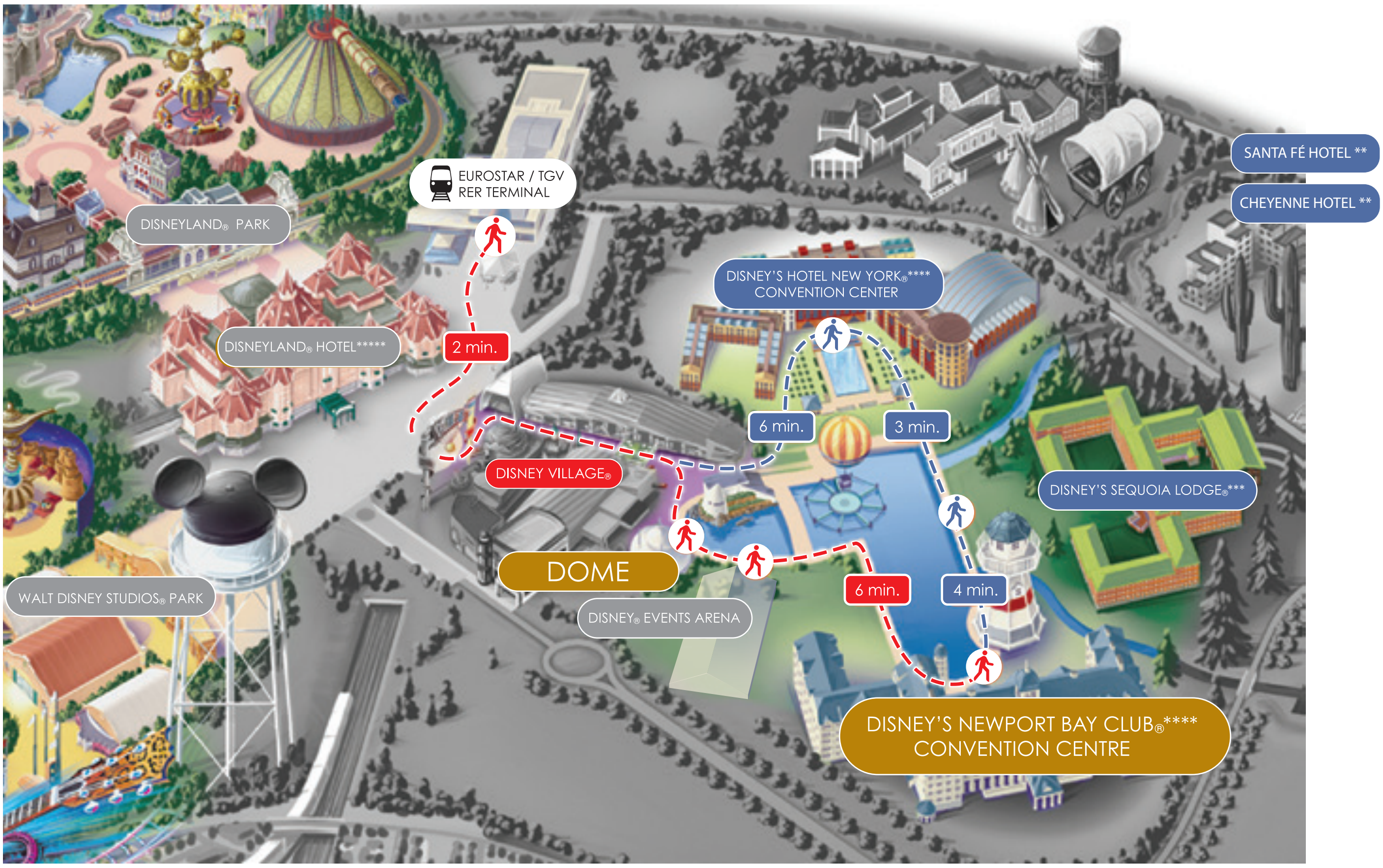


Hotels

The ICRP-ERPW delegates have special rates for these hotels:

- **Newport Bay Club Hotel** ****
  Avenue Robert Schuman
  77700 Chessy
- **Sequoïa Lodge Hotel** ***
  1 Avenue Robert Schuman
  77700 Coupvray
- **Santa Fé Hotel** **
  Avenue Robert Schuman
  77700 Coupvray
- **Cheyenne Hotel** **
  Rue du Bœuf Agile
  77700 Coupvray

Please use the hotels parkings (free of charge).
The Convention Centre is a few minutes' walk from all hotels mentioned above.
For security reasons, there is an access control at all entrances, that may be somehow time-consuming.
Other hotels are available nearby the Disney Parks.



Convention Centre

You can use the parking in front of the Convention Centre (follow the Newport Bay Club Hotel road).
Please show your registration notification to the security gate (hotel reservation or congress notification or badge).

For security reasons, there is an access control at all entrances of the Convention Centre,
that may be somehow time-consuming.

General information

Secretary Office

The Secretary Office will be open during the following hours in the Provincetown room:

- **Monday, October 9**
  15:00 - 18:00
- **Tuesday, October 10**
  08:00 - 12:30 & 13:30 - 18:00
- **Wednesday, October 11**
  08:00 - 12:30 & 13:30 - 18:00
- **Thursday, October 12**
  08:00 - 12:30 & 13:30 - 16:00

Registration/Information Desk

The front desk in the Foyer will be open for registration and information during the following hours:

- **Monday, October 9**
  08:00 - 18:00
- **Tuesday, October 10**
  08:00 - 18:00
- **Wednesday, October 11**
  08:00 - 18:00
- **Thursday, October 12**
  08:00 - 17:00

Badges

Please note that the delegates are required to wear and display their congress badge at all time in the Convention Centre. Access to all venues will be checked.

Anyone who is not registered to the conference will not be allowed to access to the sessions rooms. On site late registrations to the conference are possible at the Registration/Information Desk (front desk).

Wifi

Free Wifi is available in the Convention Centre:

1. Connect to SSID: Convention-Newport-bay Club
2. Launch your web browser: a login page will be displayed
3. Enter your email address for Free Wifi connection (12-hour free access)

Speaker

A speaker preparation desk will be located in the Secretary Office (Provincetown room).

Speakers are required to provide the secretary team with their presentation as soon as possible and no later than the start of the session.

Speaker preparation room operating time is:

- **Monday, October 9**
  15:00 - 18:00
- **Tuesday, October 10**
  08:00 - 12:30 & 13:30 - 18:00
- **Wednesday, October 11**
  08:00 - 12:30 & 13:30 - 18:00
- **Thursday, October 12**
  08:00 - 12:30

Posters

Printed posters will be displayed in the Portland Exhibition Hall for the entire duration of the conference.

Authors are encouraged to discussion during coffee breaks.

Coffee Breaks

Complimentary tea, coffee and pastries will be served in the Portland Exhibition Hall at the times specified in the programme.

Lunches

Buffets will be served at the times specified in the programme in three different restaurants located in the Convention Centre (Congress badge is mandatory):

- **Providence**
- **Yacht Club**
- **Cape Cod**

Welcome Reception

The ICRP-ERPW cocktail will be held on Tuesday, October 10, 18:00-19:30 in the Foyer.

Gala Dinner

The Gala Dinner will be held on Wednesday, October 11, 19:30-22:00 in the Dome (few minutes walk from the Convention Centre) (see the map page 93).

Please note that the access to the Gala Dinner is restricted to attendees wearing badges with red dot G and to accompanying persons wearing badges with orange dot A

If you are not registered for the Gala Dinner, please inform us by Wednesday at 12:00 at the latest. Late registration will depend on availability.

Mobile Phones

Delegates are requested to switch their mobile phone on silent mode when entering the sessions.

Language

English is the official congress language.

Parking

Free parking is available in front of the hotels.

Social Media

You may tweet about the conference using the hashtag #ICRPERPW2017

Restaurants around

Disney village® :

- **Earl of Sandwich® €**
  Fast food
- **Five Guys® €**
  Fast food
- **Starbucks Coffee €**
  Fast food
- **McDonald's® €**
  Fast food
- **New York Style Sandwiches €**
  Snacks
- **Viapano® €**
  Restaurant
- **King Ludwig's Castle €€**
  Restaurant
- **Planet Hollywood® €€**
  Restaurant
- **Rainforest Cafe® €€**
  Restaurant
- **Annette's Diner €€€**
  Restaurant
- **Café Mickey €€€**
  Restaurant
- **The Steakhouse €€€**
  Restaurant
- **Billy Bob's Country Western Saloon**
  Bar
- **Sports Bar**
  Bar

And others possibilities outside Disneyland

Sightseeing Excursions

Tickets to Disney Parks

Special rates are offered for ICRP-ERPW 2017 participants and accompanying persons [1]

Tickets available at hotel conciergeries.

- **Half-day / 1 Park :** 37 € VAT incl. valid from 2.00 pm, except week-end
- **Half-day / 2 Parks :** 52 € VAT incl. valid from 12.00, except week-end
- **1 day / 1 Park (week days) :** 44 € VAT incl. instead of 75 € VAT incl. for the public rate[2]
- **1 day / 2 Parks (week days) :** 59 € VAT incl. instead of 90 € VAT incl. for the public rate[2]
- **1 day / 1 Park (Saturday & Sunday) :** 53 € VAT incl. instead of 75 € VAT incl. for the public rate[2]
- **1 day / 2 Parks (Saturday & Sunday)** : 68 € VAT incl. instead of 90 € VAT incl. for the public rate[2]

(1)Prices in €, valid until 2nd November 2017, subject to change. The 1 day / 1 Park ticket provides access to either the Disneyland® Park or the Walt Disney Studios® Park for one day. 1 Day / 2 Parks tickets give access to both Disney Theme Parks on the same day. Dated Park tickets are valid for a pre-booked date. They are not refunded, taken back or exchanged.

(2)Public rate for a ticket valid for 1 year from the date of purchase for 1 Day / 1 Park

Disneyland® Golf

Relax and enjoy the scenery while perfecting your swing on this classic golf course, suitable for amateurs and seasoned professionals

Disneyland® Golf is open every day of the week. There are three 9-hole courses that can be combined in different ways to create a unique 18-hole course.

For information on summer and winter rates and their effective dates, please contact the Disneyland® Golf Club : +33 (1) 60 45 68 90

Around Disneyland Paris

La Vallée Village - an unique luxury experience

10 minutes from Disneyland Paris: La Vallée Village: www.lavalleevillage.com

Discover a different way of shopping in an open-air village where 120 prestigious brands offer their collections from previous seasons at discounted prices, 7 days a week. In 110 boutiques, find the biggest French and international brands of luxury and fashion.

Discover the region

Barbizon: Artists'Village

Take a relaxing wander through this quaint village and learn about some famous French landscape artists.

Lose yourself in the romance of this charming Barbizon village of artists brushed with art history. This is where seminal 19th century French landscape painters Corot, Millet and Rousseau crafted much of their work. And you can see for yourself the Barbizon school, Museum of the Painters of Barbizon (Auberge Ganne) and Rousseau and Millet's studios.

The Departmental Museum of the Painters of Barbizon, called 'Auberge Ganne': Open every day except Tuesdays, between 10:00 AM and 12:30 PM and 02:00 PM and 05:30 PM. Getting There: By car from Disneyland® Paris: Motorway A4, A104, A6. Approximately 65km.

The Castle of Blandy-les-Tours

Explore this magnificent medieval castle, one of the last remaining structures of its kind in the region.

To the Chateau Blandy les Tours near Disneyland Paris, set off on a journey to the main attraction of Seine et Marne. The Chateau Blandy les Tours near Disneyland Paris is originally built during the 100 Years War, this imposing structure has undergone many stages of modification and fortification, from a simple manor house to a wartime fortress. Today, after 15 years of painstaking excavation and restoration, its rich history is there for all to see, as well as the amazing view of the Brie countryside from the top of the keep.

Open every day from 10:30 AM to 12:30 AM and from 01:30 PM to 06:00 PM. Getting There: By car from Disneyland® Paris: Motorway A4, A104 and A5. Approximately 40 km.

Castle of Champs-sur-Marne

After 6 years of restoration, this architectural delight welcomes you to explore it's wondrously furnished interior and exquisite gardens.

Chateau of Champs-Sur-Marne was one of the first great French homes designed to look as good as it lived.

Built at the very beginning of the 18th century at the request of Louis XIV's financier, Paul Poisson de Bourvallais, the castle is one of the most complete of its kind in the Ile-de-France region.

Open every day from 10:00 AM to 12:15 PM and from 01:30 PM to 05:00 PM (except on Tuesday). Getting There: *By car from Disneyland® Paris: Motorway A4, N104 then D199. Approximately 25 km. By public transport: take the RER A from Disneyland headed for Paris. Stop at 'Noisy-Champs' (17 minutes). Then, take the bus line 312 headed for 'Gare de Noisy Champs', stop at 'Mairie de Champs'(15 minutes). Then walk to go to the castle (6 minutes).*

Castle of Fontainebleau

Immerse yourself in over 1,500 rooms and 130 stunning acres of French history and grandeur.

At the Chateau Fontainebleau, take a stroll through the grand interiors and opulent gardens of the 'House of the centuries, true dwelling of kings'. A UNESCO World Heritage site, this is the only French royal and imperial château to have been continuously inhabited

for seven centuries. Here, you'll unearth multiple galleries, chapels, museums and theatres in what is an unparalleled view of French political, royal, art and architectural history.

The Chateau Fontainebleau is open every day, from October to March: 09:30 AM - 05:00 PM (last admission is 04:15 PM). Getting There: *By car from Disneyland® Paris: Motorway A4, A104 then A6. Approximately 65 km.*

Castle of Vaux le Vicomte

Look on in wonder at this magnificent Baroque château and its gardens, which in the summer are illuminated by more than 2,000 candles.

Wander the intersecting gravel walks of the most lavish gardens in 17th century France. With dazzling interiors and stunning patterned parterres, you'll be swept away in a cool breeze of French wonder and whimsy.

The chateau Vaux le Vicomte, built between 1658 and 1661, this was the first collaboration between landscape architect André le Nôtre and painter/art theorist Charles le Brun. It sparked the beginning of the 'Louis XIV style' and had a significant influence on the design of the Palace of Versailles and architecture as a whole across Europe.

The chateau Vaux le Vicomte is open every day from mid-March to mid-November, between 10:00 AM and 06:00 PM. Getting There: *By car from Disneyland® Paris: Motorway A4, A104 then A5. Approximately 45 km.*

The City of Meaux

Relax with a gastronomic treat in this beautiful medieval town full of historic architecture.

If you like cheese, mustard and striking architecture, the visit to the city of Meaux near

Disneyland Paris is for you. Here, you'll discover one of France's only remaining Gothic cathedrals, and a palace and gardens designed by the mind behind Versailles, André Le Nôtre. There's also the unmissable Great Historical Show inside the Episcopal City. And you can enjoy it all with a bite or two of some local brie and speciality mustard.

Getting There: *By car from Disneyland® Paris: Motorway N34 then D5 or Motorway A4. Approximately 15 km. By regional bus from Disneyland® Paris: departure all year long. Bus N°19.*

The City of Provins

Pop back to medieval times at this UNESCO World Heritage site, famous for its fairs and feasts.

With the visit of the city of Provins near Disneyland Paris, explore life in the Middle Ages by venturing into the ramparts, dungeons, ancient houses and vaulted underground rooms of this medieval city.

Formerly the Count of Champagne's capital, Provins was renowned for its wondrous fairs during the 12th and 13th centuries. And there are plenty of opportunities for you to relive them, to the visit of the city of Provins near Disneyland Paris, you will find one of the biggest medieval feasts in Europe, falconry and chivalry shows, Provins by Candlelight and the Provins Harvest Festival.

Getting There: *By car from Disneyland® Paris: Motorway D231. Approximately 55km. By regional bus from Disneyland® Paris: departure all year long. Bus N°50.*

The Museum of Great War

Fully immerse yourself in this most touching of museums which, from 2014, commemorates the 100-year anniversary of the First World War.

The museum of the Great War near Disneyland Paris, built on the symbolic 'Bataille de la Marne', the museum opened in 2011, offering a fresh perspective on the first ever global war.

Many aspects of the conflict are highlighted, from the role of women to the invention of camouflage-all brought to life using the latest tour guide technology.

Open every day from 09:30 AM to 06:00 PM. Getting There: *By car from Disneyland® Paris: Motorway A4, A1 then the N330 to Meaux. Approximately 32 km. By public transport: Take the bus line 19 from Disneyland to Meaux (30 minutes). Then take the bus M6, 10, 11, 63 or 65 to go to the museum from the train station (10 minutes).*

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October 10-12 2017, Paris, France

ERPW 2ND EUROPEAN RADIOLOGICAL PROTECTION RESEARCH WEEK

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