

出國報告（出國類別：開會）

赴捷克參加 2019 第五屆環境放射性
同位素國際研討會（ENVIRA 2019）
出國報告

服務機關：行政院原子能委員會

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派赴國家/地區：捷克/布拉格

出國期間：108 年 9 月 6 日至 9 月 15 日

報告日期：108 年 10 月 29 日

摘要

本次奉派赴捷克布拉格參加 2019 年第五屆環境放射性同位素國際研討會(5th International Conference on Environmental Radioactivity, ENVIRA 2019)，其會議由捷克國家科學研究院核子物理研究所(Nuclear Physics Institute of the Czech Academy of Sciences)及捷克科技大學(Zech Technical University)共同主辦，並透過 12 個會議主題分別以專題演講方式進行，以討論及分享國際間環境放射性物質遷移分布方式、調查現況、研究與分析方法等，作為各領域相關人員放射性物質管制作為及未來研究發展趨勢之參考。

目次

壹、 出國目的與行程.....	4
貳、 會議內容.....	5
參、 心得與建議.....	20
肆、 附錄.....	22

壹、出國目的與行程

一、目的

此次赴捷克布拉格參加 2019 年第五屆環境放射性同位素國際研討會(5th International Conference on Environmental Radioactivity, ENVIRA 2019)，期望透過國際放射性同位素專家學者之研究議題及成果，了解目前放射性物質於環境中之遷移分布現況與方式、調查方法及未來趨勢等，除能了解國際趨勢及掌握最新研究資訊外，也能作為未來放射性物質作業場所輻射防護管制措施及調查方法制定之參考，並期能與國際趨勢接軌。

二、出國行程

日期	天數	地點	工作內容
108.09.06-108.09.07	2	布拉格	去程（臺北-布拉格）
108.09.08-108.09.13	6	布拉格	參加環境放射性同位素 國際研討會
108.09.14-108.09.15	2	布拉格	返程（布拉格-臺北）

貳、出席環境放射性同位素國際研討會議

一、會議簡介

環境放射性同位素國際研討會(International Conference on Environmental Radioactivity, ENVIRA)至 2011 年起每二年辦理一次，本次會議為第五屆。本會議為環境放射性同位素領域之大型國際研討會，本年度假布拉格唐喬萬尼酒店 (Hotel Don Giovanni Prague)內之會議中心舉辦(如圖 1)，集結了世界多國專家學者與研究機構，以發表與研討環境放射性同位素之研究成果及未來趨勢為主，共計約 43 國，500 人參加，參與及討論熱烈。會議辦理現況如圖 2。



圖 1. 會議辦理地點

本次ENVIRA 2019會議共為期6日，主要討論包含：(1) 加速器質譜分析法之發展及應用、(2)海洋環境放射性同位素、(3)放射性同位素於環境中之遷移分布、(4)質譜儀及放射性測量技術之發展及應用、(5)放射性同位素測量與分析技術之近期發展、(6)福島事故之環境影響、(7)天然放射性物質、(8)放射性同位素與大氣、(9)核子設施之環境影響、(10)放射性同位素與生物相、(11)放射性生態學、(12)放射化學等議題，會議議程詳如附錄所示。

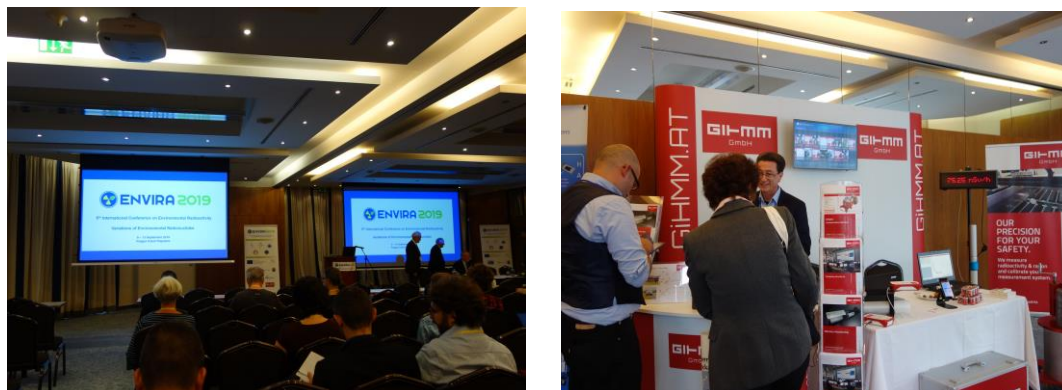


圖 2. 會議辦理情形

二、會議討論內容

本次會議之重要議題及報告研討內容分述如下：

(一) 加速器質譜儀分析法之發展及應用

加速器質譜儀分析法 (Accelerator Mass Spectrometry, 簡稱AMS)，是一種高質量解析度與低背景干擾的質譜分析方法。將待測樣品製作成離子源，利用加速器使其能量加速至百萬電子伏(MeV)級，再藉由核物理的粒子量測技術，可用來分離放射性同位素和其豐度高的其它同位素，如從碳-12 (^{12}C) 中分離碳-14 (^{14}C)，或排除分子的同質素和大部分原子同質素，例如排除氮-14(^{14}N)對碳-14(^{14}C)的影響，加速器質譜儀的結構組成如圖3，儀器實體圖如圖4。因所需樣品的量極少(約毫克等級)，又深具超高靈敏度與可信度的特性，可有效作為微量元素之質量分析方法。其中以檢測自然界存在的半衰期較長的同位素，如碳-14 (^{14}C) 為最常見。例如對木碳、泥炭、植物、骨骼、毛髮、布、麻、油漆等含有機碳的物質，及石筍、珊瑚、泉華、生物殼體等無機碳物質進行放射性碳量測，計算樣品的碳14衰變年齡，也可藉由碳-14 (^{14}C) 放射定年法用於地下水遷移分布之研究等。

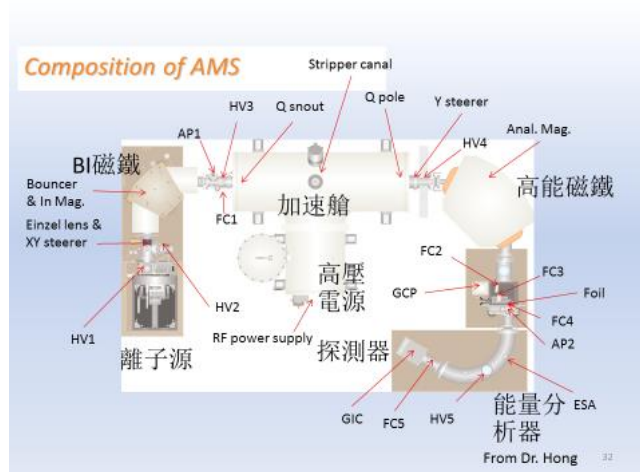


圖 3. 加速器質譜儀結構組成



圖 4. 加速器質譜儀實體圖

瑞士蘇黎世聯邦理工學院 (ETH Zurich) 離子束物理研究室學者 Hans-Arno Synal 於會議中發表研究指出，加速器質譜儀分析法之研究已行之有年，對於環境中長半衰期之放射性同位素量測扮演極重要的角色。除了常見的碳-14 (^{14}C)，也可應用於鈹-10 (^{10}Be)、鋁-26 (^{26}Al)、氯-36 (^{36}Cl)、鈣-41 (^{41}Ca) 及碘-129 (^{129}I) 等同位素之分析。該學者近年來致力於加速器質譜儀儀器技術之精進，希望縮小設備體積，研發桌上型之加速器質譜儀，提高分析之解析度，以讓加速器質譜儀能應用於更多領域之研究。

另西班牙塞維利亞大學 (Universidad de Sevilla) 學者 J. M. López-Gutiérrez 於會議中發表其與西班牙放射性廢棄物處理公司 ENRESA 合作之研究計畫，有鑑於核能發電廠除役後之放射性廢棄物處理是目前環境之重要議題，與民眾息息相關，而將加速器質譜儀分析法用於西班牙某座除役核能發電廠廢棄物，了解放射性同位素之殘留情形。相較於過去傳統之同位素量測方法常需要大量之樣本量，且耗費較長的分析時間，而加速器質譜儀分析法則有需求樣本量少且分析時間較短之優點。本次研究分析多種不同的核電廠廢棄物，例如混凝土、污泥、離子交換樹脂等物質。經研究結果顯示，加速器質譜儀可由樣本中分析出碘-129 (^{129}I)、鈣-41 (^{41}Ca)、鈾-239 (^{239}Pu) 與鈾-240 (^{240}Pu) 等元素，對於定性分析有較大的貢獻，並發現鈾-240 (^{240}Pu) 與鈾-239 (^{239}Pu) 的比值可用於推定廢棄物中放射性核種之殘留歷史，本研究仍在進行中，未來將會針對廢水中之碳-14 (^{14}C)，及錒-237 (^{237}Np)、錒-243 (^{243}Am) 及鈾(U)系同位素之分析。

(二) 放射性同位素分析技術之近期發展

東京大學農學生命科學研究所生物性化學研究室中西友子教授

(T.M.Nakanishi) 於會議中發表該研究室研發之「放射同位素即時影像系統 (Real Time Radioisotope Imaging System)」。中西教授說明，農作物對於肥料中營養元素的吸收情形，過量或過少對於生長都有很大的影響，故必需進一步研究營養元素於植物體內的代謝機制及傳輸情形。從1950年起，放射性同位素即開始被用於植物營養元素代謝機制研究之示蹤劑，最常研究的即是利用同位素鉀-42研究植物體內鉀離子之傳輸情形。但過去之實驗皆需要解剖植物樣本，利用電子顯微鏡或相關光學儀器去作後續觀察及分析，但難以得知營養素於植物體內隨著時間變化的傳輸情形，且經解剖之樣本非活體，較不足以解釋生長中植物營養素傳輸之情形，綜上考量，該實驗室研發出「放射同位素即時影像系統」。該系統之原理及設備組成如圖5及圖6。該系統將植物浸泡於含放射性同位素之溶液，並放置一用鋁製成之暗箱內，以避免環境光源影響其訊號之接受。利用放射性同位素產生 β 粒子輻射，經由碘化鈉閃爍晶體 (CsI scintillator) 及光纖板 (Fibre Optic Plate)，

將輻射訊號轉換為可見光，再經由光電倍增元件及高解析度數位照相機截取可見光轉化為電腦之數位影像。本系統約每3分鐘就可以拍一張影像。

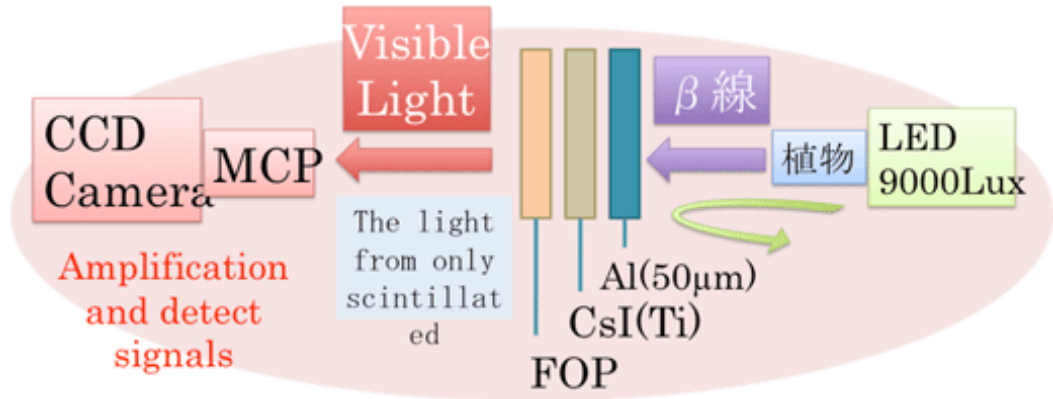


圖5. 放射同位素即時影像系統結構

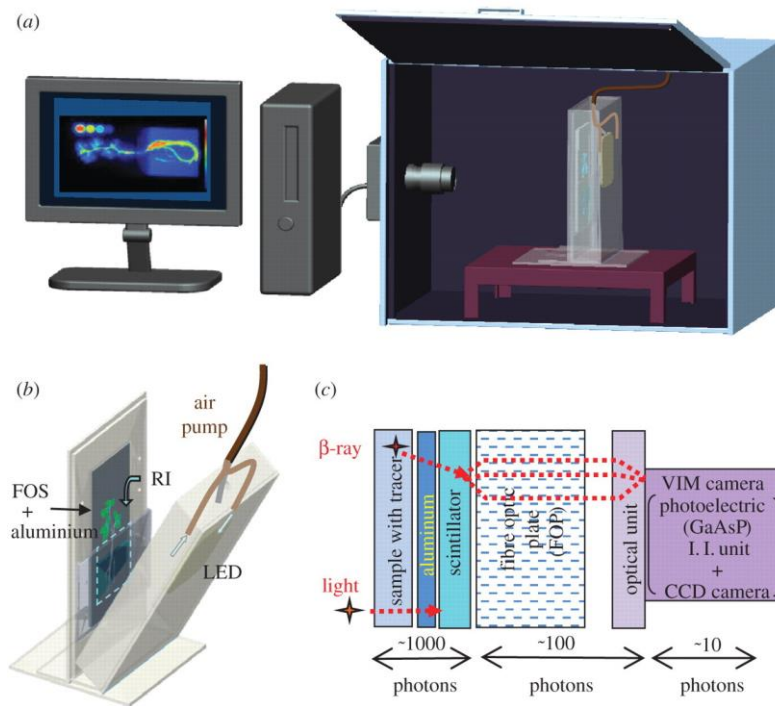


圖6. 放射同位素即時影像系統設備組成示意圖

本次發表之研究成果，係觀察同位素磷-32 (^{32}P) 於水稻秧苗中之吸收傳輸情形。本實驗準備 2 株水稻秧苗，並調配合活度 1.5MBq 磷-32 (^{32}P) 之水樣試劑，其中一株樣品置於含有 22.5 毫升水樣試劑之容器，另一株樣品置於含 15 毫升水樣試劑及 32 公克土壤之容器，並置於影像系統之暗箱內，觀察在不同培養條件下元素磷之傳輸情形。暗箱內設有 LED 燈以模擬白天及黑夜之環境條件，並以 16 小時白天、8 小時黑之模式持續進行 60 小時。實驗中每 3 分鐘即可拍一張影像。實驗結果如圖 7。實驗結果發現，元素磷在培養於水樣試劑之秧苗體內有較好之吸收情形，且吸收情形有隨時間而增加，而在含有土壤之環境下則不易生長。另亦可發現在白天環境下吸收效率大於黑夜環境。此影像系統成功應用於觀察活體植物營養素隨時間之吸收情形，對於未來農業種植之環境或施肥條件控制有很大之幫助。除了同位素磷，未來也持續針對植物較重要之營養素，例用鈣、硫、鈉及鐵等同位素結合此影像系統來作研究。

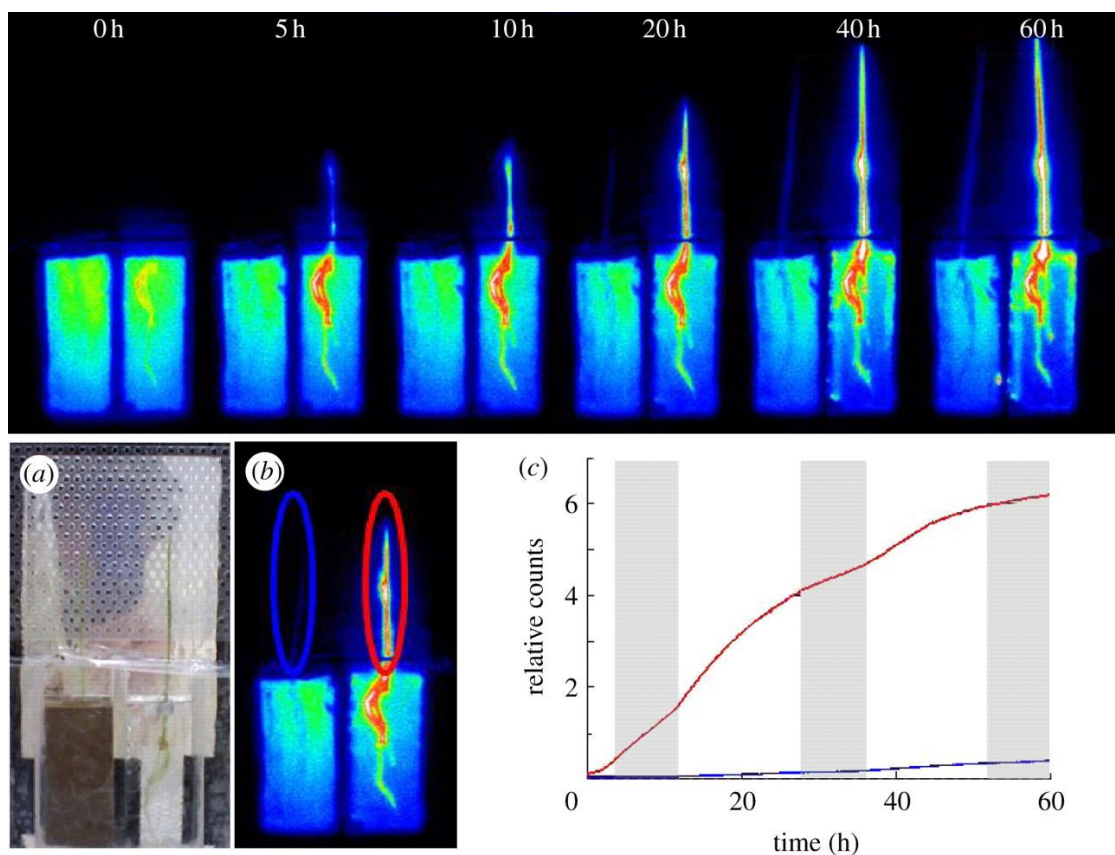


圖7. 放射性同位素即時影像系統研究成果

(三) 放射性同位素於環境中之遷移分布

核能發電廠、放射性廢棄物處理儲存場，以及核子試爆或核子事故等，其產生的放射性物質是否對環境造成輻射污染，或使民眾接受輻射曝露而影響健康及生活，是全球長期關注的議題。愛爾蘭環境保護署輻射防護及環境監測辦公室（Environmental Protection Agency, Office of Radiation Protection and Environmental Monitoring, Ireland）於會議中發表愛爾蘭長達 35 年的環境輻射監測的長期研究，並分享 2014-2015 年之研究結果。有鑑於塞拉菲爾德核燃料再處理廠（Sellafield Nuclear Fuel Reprocessing Plant）是位於英國西邊一個大型的用過核燃料再處理廠，及核能發電廠除役後之放射性廢棄物處理廠，曾經也是一座大型的核能發電廠，因其位於愛爾蘭的東北邊，愛爾蘭環保署長期關注該廠址之放射性物質是否對於愛爾蘭環境及公共衛生造成污染及健康危害，故於約 1980 年起開始規畫執行長期性之調查研究計畫。本計畫的目的是監測愛爾蘭各項重要環境指標之輻射劑量率，及分析民眾所接受的輻射曝露來源及劑量，以讓民眾處在一個輻射安全的環境，減少民眾擔憂，提高生活品質。本研究監測項目包含：

- (1). 大氣中的輻射：包含空氣微粒中之放射性物質濃度、民眾吸入放射性物質之推估劑量、雨水中之放射性物質濃度、固定輻射監測站之連續性環境輻射劑量率監測等。
- (2). 食物中的輻射：包含牛奶、食品、穀物及飲用水中的放射性物質濃度，以及民眾經牛奶食入體內之放射性物質含量。
- (3). 海洋環境中的輻射：包含海水、海洋沉積物以及魚類及帶殼魚類的放射性物質濃度，以及民眾經魚類及帶殼魚類食入體內曝露之輻射劑量。

經研究結果分析發現，愛爾蘭民眾之年輻射曝露劑量約為 4.037mSv，其中最大部分之曝露來源為環境天然輻射(86%，3.48mSv)，又以室內空氣中之氡氣為最主要之來源。有關人造輻射曝露部分，約佔了 14%(0.557mSv)，其中以醫療輻射曝露為主(約 0.546mSv)，其餘人造輻射所貢獻之輻射劑量小於 1%。愛爾蘭民眾主要輻射曝露來源統計詳如圖 8。

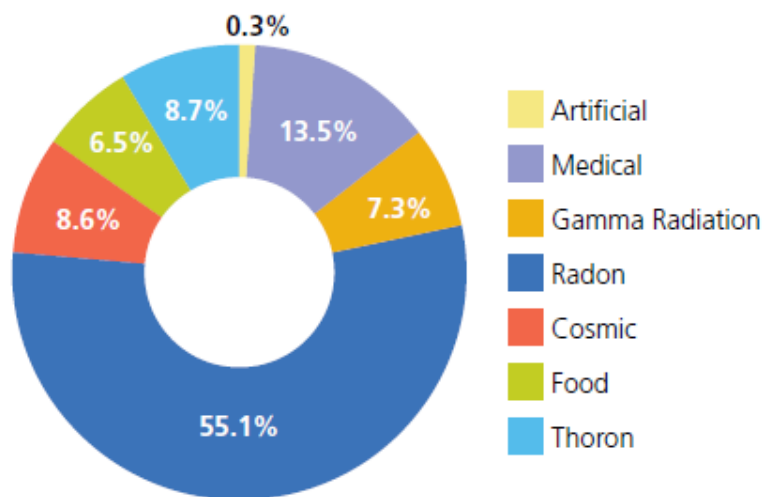


圖8. 愛爾蘭民眾主要輻射曝露源統計圖

有關大氣輻射之監測結果詳如表 1。本監測數據主要來自愛爾蘭設置的 15 個環境輻射監測站，藉由即時性的環境輻射劑量率監測，以及空氣及雨水之採樣分析等之研究調查結果。另有關民眾吸入放射性物質之推估劑量部份，係以民眾平均呼吸換氣率 22.2 m³/day 計算。綜合而言，愛爾蘭大氣輻射劑量與過去相比為一致，甚至稍微降低，並沒有增加的趨勢。

監測項目	監測結果
空氣微粒 Cs-137 濃度	3.2x10 ⁻⁷ (Bq/m ³)
空氣微粒 Be-7 濃度	2.0x10 ⁻³ (Bq/m ³)
吸入 Cs-137 之推估劑量	1.1x10 ⁻⁴ (μ Sv)
環境輻射劑量率	0.06-0.10(μ Sv/h)

表 1.大氣輻監測結果

有關食物中輻射監測結果詳如表 2。牛奶中之放射性物質含量以天然放射性物質鉀-40 為主，而僅有部分樣品檢測出微量之鋇-90，銫-137 則皆未檢出。民眾經牛奶食入體內之放射性物質含量部分，係以成人飲用年奶 78 公斤/年及幼童 150 公斤/年之攝取率來計算。而食品、穀物亦檢測出天然放射性物質鉀-40 為主，未有人工放射性物質銫-137 檢出。飲用水放射性物質濃度檢測結果皆低於最低可測值。

監測項目	監測結果
牛奶 K-40 含量	47.4(Bq/l)
經牛奶攝影之食入劑量-成人	0.16(μ Sv)
經牛奶攝影之食入劑量-幼童	1.68(μ Sv)
食品 K-40 含量	54.65(Bq/Kg)
穀物 K-40 含量	93.67(Bq/Kg)
飲用水	< MDL

表 2.食物輻射劑量監測結果

有關海洋中的輻射部份，主要關注位於愛爾蘭東北方之塞拉菲爾德核燃料再處理廠排放之低放射性廢水是否對海洋環境及漁類造成影響。監測結果詳如表 3。結果顯示，海水、海洋沉積物以含有放射性物質銫-137 為主，海草除了銫-137，並可檢測出銻-99，但其檢測結果與先前年度之調查無顯著差異。另漁類及貝類以含有放射性物質銫-137 為主，而不同漁種之含量也有所差異性。採樣之漁類樣品中，以鱈魚檢測出之銫-137 含量相對較高(0.43 Bq/Kg)，而帶殼魚類以龍蝦銫-137 含量相對較高(0.20 Bq/Kg)，但其檢測結果與先前年度之調查無顯著差異。有關民眾經魚類及帶殼魚類食入體內曝露之輻射劑量部分，係分一般及高度魚類食用者兩組別來分析，結果顯示高度魚類食用者藉由魚類所造成之體內輻射曝露較高，但皆遠低於民眾劑量限值每年 1 毫西弗。

監測項目	監測結果
海水 Cs-137 含量	0.007(Bq/l)
海洋沉積物 Cs-137 含量	2.9 (Bq/Kg)
海草 Cs-137 含量	1.25(Bq/Kg)
海草 Tc-99 含量	149.4(Bq/Kg)
魚類 Cs-137 含量	0.19(Bq/Kg)
帶殼魚類 Cs-137 含量	0.13(Bq/Kg)
一般魚類食用者食入劑量	0.08(μ Sv)
高度魚類食用者食入劑量	0.37(μ Sv)

表 3.海洋輻射監測結果

本研究結果發現，塞拉菲爾德核燃料再處理廠對於愛爾蘭民眾輻射曝露劑量貢獻比例很低，且目前各監測結果並未發現輻射曝露有對民眾造成健康危害之情形，但政府並將研究結果作成宣導文宣如圖 9，認為必需公佈有科學依據之資訊，才能有效降低民眾對於環境輻射安全之疑慮，愛爾蘭將持續執行本長期研究計畫，以維持環境輻射安全。

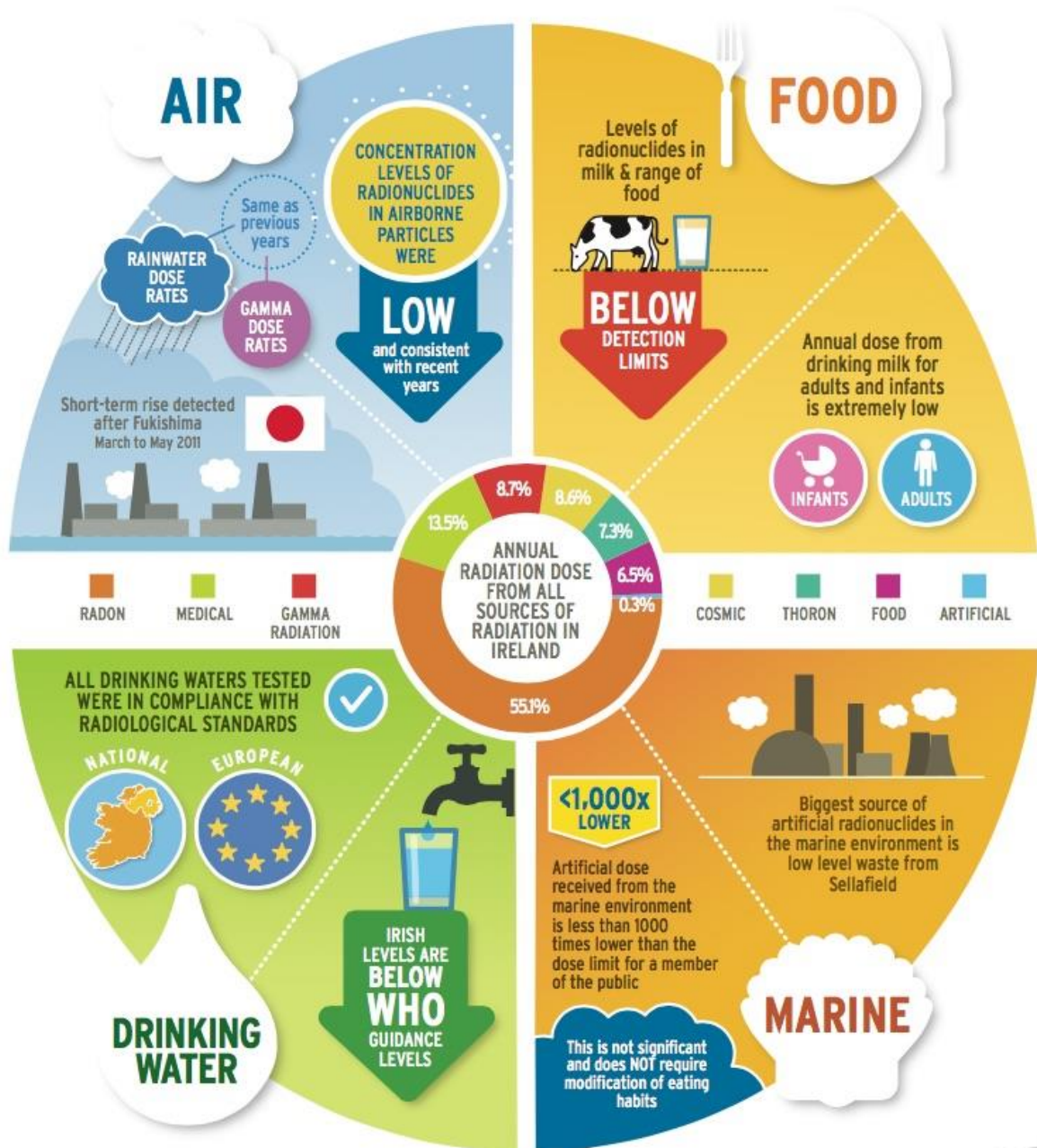


圖 9.愛爾蘭環境輻射大眾宣導

(四) 天然放射性物質

(1). 廢棄物與天然放射性物質之研究

美國路易斯安那州立大學物理與天文學系教授 Wei-Hsung Wang 於會議中發表建築廢棄物與天然放射性物質之研究。研究內容為行政大樓因有翻修需求，故進行拆除工程。拆除後的廢金屬堆放於一大型廢棄物儲存箱體如圖 10，並載送至金屬廢棄物回收場，結果卡車經過輻射門框偵檢器後發出警報，故整批廢金屬又被送回原建築工地，並請相關單位進行輻射源之調查及研究。經調查本批廢棄物體積約有 15 立方公尺，主要包含建築物拆除之廢棄金屬及通風設備管路等物質。調查人員持蓋革偵檢器及碘化鈉偵檢器進行初步調查，並未發現此批廢棄金屬有明顯之輻射劑量。接著，調查人員進一步調查究竟是此批金屬廢棄物還是廢棄物儲存箱體有遭受輻射污染而作動回收場之門框偵檢器，故將全部廢金屬從箱體移開，結果於底部發現有部分屋頂磚瓦之碎片，因磚瓦並非預期送至金屬廢棄物回收場之物質，且懷疑其是否造成門框偵檢器作動之原因，故先將之移除裝袋後，再將原金屬廢棄物堆置入廢棄物儲存箱體內，再次運送至回收場，結果本次廢棄物成功通過門框偵檢器，可見屋頂磚瓦之碎片應為產生輻射訊號之來源。後來將拆除下約 30 袋的屋頂磚瓦進行初步量測，有檢測出比背景值稍高的輻射劑量率，接著取部分樣本進一步用高純銻半導體偵檢器進行核種分析，結果顯示該瓦片含有鉀-40(^{40}K)、鈾-238(^{238}U)及釷-232(^{232}Th)等核種，皆屬天然放射性物質，濃度皆低於豁免管制標準。另比較屋頂磚瓦與天然放射性物質相關文獻指出，磚瓦成份主要含有陶土及釉料，其成份亦含有微量天然放射性物質，與本次調查結果相符。本次研究調查結論表示，屋頂瓦片含有天然放射性物質，另本案回收場之門框偵檢器警報值設定有過低之情形，可進一步檢討分析，而廢棄物之輻射污染調查人員需要更多訓練與經驗之累積。



圖 10.建築廢棄金屬儲存箱體

(2). 室內天然放射性物質氡氣之研究

印尼核能管制局 Ahmad Ciptadi Syuryavin 先生與韓國慶北大學 (Kyungpook National University) 於會議中發表印尼與韓國有關室內環境中氡氣對環境影響及管制之相關研究。該學者表示，氡氣 (^{222}Rn) 是經由鈾衰變而來，半衰期很短，約 3.8 天。依過去研究指出，氡氣在室外環境比較容易被稀釋，平均室外活度濃度約 10 Bq/m^3 ，而在室內環境則不易被稀釋，故較易累積，平均室內濃度約 50 Bq/m^3 ，但此數字仍因不同國家之環境差異而有很大的變異度。又依過去研究指出，室內氡氣曝露被懷疑與人類肺癌及胃癌有關，但仍需要更進一步研究。故本研究係對於印尼與韓國不同環境下之室內氡氣作調查，希望能有助於訂定室內氡氣標準，及未來之氡氣保護措施等。本研究於韓國與印尼之公共建築物室內進行氡氣調查。經調查發現氡氣曝露與國家地理環境條件有關，例如海拔高度的變異性及地震帶。比較韓國與印尼，韓國相較之下海拔高度的變異性相較於印尼小，且較少地震帶，故研究發現印尼各採樣地區之環境氡氣濃度變異度相較於韓國大，如表 4 及表 5。

Province (No)	Range (Bq/m^3)	Mean + SD (Bq/m^3)
Gangwon.(45)	22.3-133.7	55.0±29.2
Gyeonggi.(56)	19.0-169.3	47.5±23.3
Gyeongsangnam.(42)	19.1-87.3	37.3±14.6
Gyeongsangbuk (66)	18.6-317.7	53.8±40.7
Jeollanam (43)	21.6-194.5	58.8±39.1
Jeollabuk (26)	25.2-103.9	55.8±21.6
Jeju (9)	15.2-53.5	28.2±11.2
Chungcheongnam (37)	24.4-202.5	56.7±33.1
Chungcheongbuk (27)	31.6-236.5	70.0±53.2
Total average	15.2-317.7	52.6±33.1
Effective Dose (mSv/y)		0.37

表 4. 韓國室內環境氡氣濃度

Province (No)	Range (Bq/m ³)	Mean (Bq/m ³)
Lampung (32)	16.0-33.0	23.5
Bengkulu (12)	20.0-125.0	50.0
Riau (29)	33.3-83.3	56.2
Banten (80)	5.5-55.5	28.2
Jawa Barat (187)	3.0-155.0	43.0
Jakarta (255)	2.0-127.3	27.0
Jawa Timur (32)	4.7-168	17.3
Sulawesi Selatan		200
Bali		208.3
Total average		72.6
Effective Dose (mSv/y)		0.52

表 5. 印尼室內環境氡氣濃度

本研究另對於室外環境、室內環境及建材之氡氣濃度進行比較及分析，分析結果如表 6 及表 7。研究發現，韓國之環境氡氣大致低於國際標準，而印尼則有較高的氡氣曝露。

	Samples	Mean	Effective Dose (mSv/y)
Indoor	Public buildings [1]	52.6±33.1 Bq/m ³	0.37
	Houses [2]	129.0±29 Bq/m ³	0.9
	College rooms [3]	59.7±6.0 Bq/m ³	0.43
	Elementary school [4]	49.0 Bq/m ³	0.41
Outdoor	Atmosphere [5]	3.2 nGy/h	0.28
Building materials	Frame construction materials	287.8 Bq/m ³	2.07
	Finishing materials [6]	83.81 Bq/m ³	0.6
Reference value:			
<ul style="list-style-type: none"> • 1 mSv (ICRP: public dose limit) • 148 Bq/m³ (EPA: radon concentration) • 4 pCi/l (EPA: radon concentration) • 26.2 mBq/m²s (UNSCEAR, 2000: radon exhalation) 			

表 6. 韓國不同環境與建材之氡氣曝露濃度比較表

	Samples	Mean	Effective Dose (mSv/y)
Indoor	Public buildings [7]	35.1 Bq/m ³	0.37
	Research Buildings [8]	40.0 Bq/m ³	0.37
	Caves [9]	200 Bq/m ³	>5
Outdoor	Bangka Belitung soil [10]	48.11 mBq/m ² s	-
	Atmosphere [9]	351.5 Bq/m ³	2.53
Building materials	Bricks [11]	66.6 Bq/m ³	0.48
	Gypsum, <100cm from ceiling [12]	208.3 Bq/m ³	1.5
Reference value:			
<ul style="list-style-type: none"> • 1 mSv (ICRP: public dose limit) • 148 Bq/m³ (EPA: radon concentration) • 4 pCi/l (EPA: radon concentration) • 26.2 mBq/m²s (UNSCEAR, 2000: radon exhalation) 			

表 7. 印尼不同環境與建材之氡氣曝露濃度比較表

有關於訂定氡氣環境管制標準之探討，氡氣約佔天然輻射之 50%，目前國際調查顯示，民眾年曝露環境天然輻射之有效劑量為 2.4mSv，依本研究結果發現韓國及印尼民眾推估之氡氣年曝露有效劑量為 0.7mSv 及 1.7mSv，皆低於 2.4mSv，故 2.4mSv 可考量作為一個氡氣曝露之參考標準，但部分地區因地理環境影響因素，氡氣曝露濃度可能較高，需透過個別環境監測才能有效管制。

故綜合上述，本研究發現地理環境條件為影響氡氣濃度重要因素，而建材產生之氡氣也是影響因素之一，本會已有訂定我國建材天然放射性物質管制標準，未來仍會持續關注此議題，配合相關調查研究，為民眾安全把關。

(3). 採礦工人氡氣曝露之研究

匈牙利潘諾尼亞大學(University of Pannonia)放射化學與放射生態學研究所學者 A. Shahroghi 於會議中發表採礦工人與天然放射性物質氡氣曝露之相關研究。伊朗卡尚市(Kashan)周邊有一大型頁岩採礦廠，該頁岩主要由火山灰與泥土沉積而成，而採礦場面積約有 14 萬平方公尺，採礦場內有採礦工人、司機、工程人員及行政人員等不同職務之人員，本研究挑選於採礦場內不同區域、不同職務之 13 位工作人員，請其佩帶 CR-39 個人氡氣偵檢採樣器，進而推估不同職務人員每年藉由呼吸曝露氡氣的濃度及輻射劑量率。

調查結果如表 8。依結果顯示，採礦場之工作人員每年平均工作時數為 1,600~2,010 小時，採礦工人之年平均工時為最高，最低則為司機。而有關氡氣曝露濃度，採礦工人之曝露濃度最高，曝露最低者為司機。故本研究發現採礦工人有較高之氡氣曝露情形，而氡氣曝露與工作性質及環境有關，故工作人員氡氣曝露需要藉由更多不同工作環境的調查，才能進一步規劃相關防護措施。

Worker	Working Hours	²²²Rn exposure (Bqm⁻³)	Annual effective dose (mSvy⁻¹)
Miner	2010	168	3.8
Office	1960	43	0.9
Driver	2010	55	1
Office	1960	43	0.9
Miner	2010	101	2.3
Miner	2010	106	2.4
Office	1960	53	1.1
Engineer	1670	44	0.8
Engineer	1820	56	1.1
Driver	1600	39	0.7
Miner	2010	98	2.2
Miner	2010	90	2
Miner	2010	148	3.2

表 8. 採礦場不同職務工作人員氡氣曝露濃度採樣分析比較表

(五) 福島核災事故之環境影響

東京上智大學(Sophia University)教授 katsumi Hirose於會議中發表福島核災事故之放射性落塵對於大氣的影響。2011年3月11日發生福島核災後，至該年3月底之間為放射性落塵排放於大氣環境最主要之期間，其中主要測得之揮發性放射性物質及總活度如表9，以放射性物質碘(I)及銫(Cs)為主。而上述放射性落塵約有20%沉降於日本本州，剩餘之80%則沉降於北太平洋隨著洋流於海洋環境流佈。發生事故後影響最大的地方為福島縣，當時空氣放射性落塵以含有放射性物質銫137為主，測得之單位面積活度達到185kBq/m²，擴散之範圍達到1,700平方公里，即便於24,000平方公里之範圍外仍測得約10kBq/m²之單位面積活度。而事故大約十天後，大氣中的銫-137逐漸減少，但事故後的放射性落塵對於環境的影響仍是值得持續追蹤研究的，故本研究至今已執行了八年。

事故發生後，本研究於2011年3月12日至25日進行初期放射性物質大氣影響之調查分析，結果顯示表面空氣中以放射性物質銫-137(¹³⁷Cs)為主，影響範圍為日本福島縣及關東地區為主，本期間以每一小時為區間進行連續性之空氣採樣分析，觀察銫-137(¹³⁷Cs)活度變化之趨勢。結果發現於福島縣內之雙葉町(距福島核電廠西北方3.28公里)及楢葉町(距福島核電廠南方17.5公里)測得有10次之活度高峰，而2011年3月12日下午3點銫-137(¹³⁷Cs)活度濃度最高，活度濃度為13.6kBq/m³。而2011年4至6月後，空氣中之銫-137(¹³⁷Cs)含量已有下降趨勢，直至監測至2018年止，空氣中銫-137(¹³⁷Cs)之活度濃度已逐年下降。故本研究將持續追蹤調查，以了解福島事故對大氣環境造成的影響。

監測項目	監測結果(PBq)
Xe-133	11,000
Cs-137	15
Cs-134	18
I-131	160

表 9.福島事故大氣放射性物質釋放總活度監測結果

參、心得與建議

本次至布拉格參加第五屆環境放射性同位素國際研討會，藉由各國家研究人員發表之研究議題及成果，深刻體會放射性同位素在學術研究、環境、生活及健康等領域佔有很重要的地位。在環境領域的學術研究上，放射性同位素可扮演示蹤劑的角色，作為大氣、水文、土壤等隨時間變化趨勢的重要指標，更有助於作為農作物施肥技術之研究；放射化學研究領域學者則研究，何種同位素作為研究指標較為適當。另隨著放射性同位素在各領域的應用，隨之而來的，就是探討其對於環境的影響及健康的風險，這也是與業務上最有相關的議題。放射性同位素背後含有很深的理論基礎，必須對常見各種同位素的特性有一定的了解後，才能進一步執行環境調查研究設計，進行後續選定目標同位素、採樣方式及分析方法等，而藉由相關議題的學術研究，也才能提供於政府單位主管機關作為法規制定及管制作為的參考依據。本次會議更發現國際上對於放射性同位素與環境及生態之影響有很高的重視度，從聽取各研究人員的報告中，體會出大家皆認同放射性同位素對於各領域皆有很大的貢獻，故要藉由更多研究來取得其與環境及健康之平衡方式，而不是為了降低風險而限制放射性同位素的使用，值得省思。綜合而言之，本次會議對於放射性同位素的學理特性、應用層面、分析方法、環境影響、健康風險、國際管制趨勢等皆吸取相當多的新知，對於未來實務管制上有很大的助益。

另有關本次出國會議，部分建議事項如下：

1. 持續參與國際放射性同位素或輻射防護管制相關會議，掌握國際趨勢：

本單位主要業務為管制放射性同位素作業場所環境與人員之安全，而放射性同位素應用領域及技術日新月異，推陳出新，故需要隨時掌握目前同位素應用之國際趨勢，了解其應用方式與技術等，才能有助於制定國內相關作業場所的管制作為，以維護輻射作業安全。

2. 蒐集國際有關天然放射性同位素相關法規資訊，俾利我國法規訂定之參考：

本次會議中發現天然放射性同位素的輻射曝露亦受到日漸關注，例如有多位講者於會議中報告有關氡氣曝露與健康風險之相關研究。本議題雖然未來還有很多待探討及釐清之處，但由於天然放射性物質之輻射曝露與民眾生活息息相關，本單位為國內輻射防護之主管機關，必須掌握各國目前之法規資訊，或預計修法之內容，作為我國未來因應天然放射性物質議題法規修定之參考。

3. 持續辦理輻射作業場所稽查管制人員之專業技術訓練，以提升管制能量：

本單位為國內輻射防護之主管機關，業務相關人員須藉由持續的教育訓練，提升放射性物質之相關專業技術，俾利提升本單位在我國輻射作業場所稽查及管制上之成效，以達輻射安全的目的。

肆、附錄

ENVIRA 2019會議議程

ENVIRA 2019

5th International Conference on Environmental Radioactivity

Variations of environmental radionuclides

8 – 13 September 2019
Prague Czech Republic

PROGRAMME



EUROPEAN UNION
European Structural and Investment Funds
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PROGRAMME DAY 1

Sunday, 8 September 2019

15:00 – 18:00	Registration [Exhibition area of Don Giovanni Hotel, 1 st floor]
18:00 – 20:00	Welcome Party [Exhibition area of Don Giovanni Hotel, 1 st floor]



PROGRAMME DAY 2

Monday, 9 September 2019

07:30 – 11:00	Registration [Exhibition area of Don Giovanni Hotel, 1 st floor]
08:30 – 09:00	Conference Opening [Room Don Giovanni 2-3, 2 nd floor] I. Světlík
09:00 – 11:00	Plenary Session I [Room Don Giovanni 2-3, 2 nd floor] Chair: P.P. Povinec, I. Světlík
09:00	T.M. Nakanishi , Japan <i>Real-time RI imaging of ¹⁴C-carbon dioxide fixation and movement in a plant (147)</i>
09:30	I. Levin , Germany <i>Fifty years of radiocarbon applications in modern carbon cycle research (18)</i> I. Levin, S. Hammer
10:00	H-A. Synal , Switzerland <i>Analytic progress in AMS and related opportunities for applications with long-lived radionuclides (286)</i>
10:30	P. Steier , Austria <i>The advantages of measuring actinides with AMS (331)</i> P. Steier, K. Hain, M. Kern, A. Wiederin, R. Gosler
11:00 – 11:30	Coffee break

11:30 – 13:00	Parallel Session 1A AMS and Applications [Room Don Giovanni 2-3, 2 nd floor] Chair: P. Steier, H-A. Synal	Parallel Session 1B Marine Environment [Room Donna Anna/Donna Elvira, 1 st floor] Chair: G. Lujaniene, S-H. Lee
11:30 11:45 12:00 12:15 12:30 12:45	<p>J. Lachner, Austria <i>Ion-laser interaction mass spectrometry: green light for a sensitive detection of long-lived radionuclides (232)</i> J. Lachner, A. Wieser, M. Honda, O. Marchhart, M. Martschini, A. Priller, P. Steier, R. Golser</p> <p>S. Maxeiner, Switzerland <i>MILEA: a new compact 300 kV multi-isotope AMS system (271)</i> S. Maxeiner, A.M. Müller, M. Christl, P. Gautschi, H-A. Synal, C. Vockenhuber, L. Wacker</p> <p>M. García-León, Spain <i>Radionuclide determination by Accelerator Mass Spectrometry (AMS) in materials from decommissioning of nuclear facilities (102)</i> M. García-León, J.M. López-Gutiérrez, E. Chamizo, C. Vivo-Vilches</p> <p>J. Zeman, Slovakia <i>Development of methods for AMS analysis of long-lived radionuclides at the CENTA facility (262)</i> J. Zeman, M. Jeřkovský, J. Kaizer, I. Kontul', J. Pánik, P.P. Povinec</p> <p>A. VII Bautista, Philippines <i>High-resolution ¹²⁹I record of years 1956 – 2007 from an ice core in SE Dome Site, Greenland (220)</i> A. VII Bautista, S.J. Limlingan, H. Matsuzaki, M. Toya, Y. Miyake, K. Horiuchi, Y. Iizuka</p> <p>R. Agnihotri, India <i>Stable isotope mass-spectrometer coupled graphite preparation laboratory for radiocarbon dating at Birbal Sahni Institute of Palaeosciences, Lucknow (India): a status report (116)</i> R. Agnihotri, S.K.S. Singh, N. Patel, R. Sharma, P. Kumar, C. Sundeep</p>	<p>S. O'Toole, Ireland <i>Radioactivity in the Irish marine environment (92)</i></p> <p>G. Olszewski, Sweden <i>Actinides distribution in anoxic sediments close to Swedish nuclear facility (274)</i> G. Olszewski, P. Törnquist, P. Lindahl, M. Eriksson, H. Pettersson</p> <p>J. Qiao, Denmark <i>²³³U – ²³⁶U oceanic tracer studies in the Baltic Sea and the Arctic Ocean (219)</i> J. Qiao, P. Steier, K. Hain</p> <p>A. del C. Arriola Velásquez, Spain <i>Variations of natural radionuclides as tracers of beach sedimentary dynamics (204)</i> A. del C. Arriola Velásquez, A.M. Tejera Cruz, J. González Guerra, I. Alonso Bilbao, H. Alonso Hernández, M.A. Arnedo Ayensa, J. García Rubiano, P. Martel Escobar</p> <p>S. Tan, Philippines <i>Iodine-129 as an environmental tracer for salinity origin in groundwater samples in Pampanga, Philippines (217)</i> S. Tan, A. VII Bautista, H. Matsuzaki, N. Mendoza, M. Puthenpurekal, C. Racadio, A. Resurreccion</p> <p>M. Simonsen, Norway <i>Impact of dynamic speciation in model simulations of river-discharged radionuclides in the marine environment (244)</i> M. Simonsen, O.C. Lind, Ø. Saetra, P. E. Isachsen, H-C. Teien, J. Albretsen, B. Salbu</p>
13:00 – 14:00	Lunch	

14:00 – 16:00	Parallel Session 2A Radionuclide Transport in the Environment [Room Don Giovanni 2-3, 2 nd floor] Chair: I. Levin, M. Laubenstein	Parallel Session 2B Mass Spectrometry and Radiometrics [Room Donna Anna/Donna Elvira, 1 st floor] Chair: G. Wallová, T. Kovács
14:00 14:15 14:30 14:45 15:00 15:15 15:30 15:45	<p>K. Brimo, France <i>Semi mechanistic modelling of the long soil to grass transfer of ¹³⁷Cs in French pastures (122)</i> K. Brimo, L. Pourcelot, M. A. Gonze</p> <p>Y. Xu, China <i>Speciation of global fallout plutonium isotopes in natural soil particles and the implications for environmental tracing studies (171)</i> Y. Xu, S. Pan, Y. Hao</p> <p>C. Antonelli, France <i>Mass balance and transit times of artificial radionuclides transported from the Rhone River to the Mediterranean Sea (76)</i> C. Antonelli, O. Radkovitch, F. Eyrolle, H. Lepage</p> <p>M.A. Hernandez Ceballos, Italy <i>Dispersion and ground deposition characteristics of radioactive material according to air mass classification for enhancing the preparedness to N/R emergencies (90)</i> M.A. Hernandez Ceballos, M. Sangiorgi, B. Garcia Puerta, M. Montero, C. Trueba</p> <p>S. Reygrobellet, France <i>Reconstruction of the impact to biota of former releases of alpha emitters in the Loire River (26)</i> S. Reygrobellet, P. Boyer</p> <p>N. Kuzmenkova, Russia <i>Application of natural and artificial radionuclides for exploration of sedimentation in the lake Huko (West Caucasus) (211)</i> N. Kuzmenkova, M. Ivanov, A. Grachev, A. Rozhkova, V. Golosov</p> <p>Y. Kikawada, Japan <i>Kusatsu-Shirane volcano, Japan, using radioactive caesium as a hydrological trace (196)</i> Y. Hirayama, A. Okawa, K. Nakamachi, T. Aoyama, Y. Okada, T. Oi, K. Hirose, Y. Kikawada</p> <p>D. Taieb Errahmani, Algeria <i>Temporal variability of environmental radioactivity in bulk deposition (rainwater and dust) from Northern Algeria (146)</i> D. Taieb Errahmani, A. Noureddine, M. Boulahdid, A. Hammadi, M. Maache</p>	<p>S. Nagorny, Canada <i>A new approach to detect of low counting rate using an ultra-low-background HPGe detector (255)</i> S. Nagorny, S. Nisi, M. Laubenstein</p> <p>A. de Vismes Ott, France <i>Low-level measurements of environmental samples by gamma-ray spectrometry using well-type germanium detectors (70)</i> A. de Vismes Ott, X. Cagnat, O. Masson, F. Eyrolle, C. Ardois</p> <p>S. Lim, Korea <i>Determination of radon leakage from sample container for gamma spectrometry measurement of Ra-226 (130)</i> N.S. Syam, S. Lim, S. Lee, H. Lee</p> <p>C. Tsabaris, Greece <i>Underwater in-situ gamma-ray spectrometry using medium and low-resolution detection (280)</i> C. Tsabaris, F. Pappa, N. Maragos, G. Eleftheriou</p> <p>G. Eleftheriou, Greece <i>Continuous monitoring of submarine spring by means of gamma-ray spectrometry at Anavalos, Greece (273)</i> G. Eleftheriou, F. Pappa, N. Maragos, C. Tsabaris</p> <p>S. Y. Han, Korea <i>Preliminary study on the estimation of minimum detectable activity and the efficiency for real-time marine monitoring system (123)</i> S.Y. Han, S. Maeng, H.Y. Lee, S.J. Park, S.Y. Lim, S.H. Lee</p> <p>Y. Ogata, Japan <i>Convenient and rapid measurement of radiostrontium in seawater (206)</i> Y. Ogata, H. Minowa, Y. Kato, S. Kojima</p> <p>G. Immé, Italy <i>In soil radon anomalies and volcanic activity on Mt. Etna (Italy) (278)</i> M. Ichedef, S. Giammanco, M. Neri, R. Catalano, G. Immé, D. Morelli, F. Muré, N. Giudice</p>
16:00 – 16:30	Coffee break	

16:30 – 18:30	Parallel Session 3A Recent Developments in Analytical Methods I [Room Don Giovanni 2-3, 2 nd floor] Chair: N. Kuzmenkova, S. Pan	Parallel Session 3B International Projects and Reference Materials [Room Donna Anna/Donna Elvira, 1 st floor] Chair: M.K. Pham, D. Degering
16:30 16:45 17:00 17:15 17:30 17:45 18:00 18:15	<p>L. Benedik, Slovenia <i>Decomposition of solid samples by various techniques with emphasis on actinides content (225)</i> L. Benedik, A.M. Pilar, H. Prosen</p> <p>A. Barkleit, Germany <i>Influence of common decorporation agents on the speciation of trivalent f-elements in serum – a luminescence spectroscopic study (105)</i> A. Barkleit, A. Heller</p> <p>J. Stadler, Germany <i>Direct speciation of radionuclides in plant parts by time-resolved laser fluorescence spectroscopy (TRLFS) and desorption electrospray ionization mass spectroscopy (DESI MS) (175)</i> J. Stadler, A. Kogiomtzidis, M. Steppert, M. Schmidt, N. Huittinen, M. Weiss, F. Köhler, T. Stumpf, C. Walther</p> <p>N. Todorovic, Serbia <i>Improvement of the detection efficiency for ²¹⁰Pb determination in water samples by Cherenkov radiation (56)</i> N. Todorovic, J. Nikolov, I. Stojkovic, B. Tenjovic, M. Vranes, S. Gadzuric</p> <p>N. Rabia, Algeria <i>Mineralogical characterization of a soil intended for phytoremediation (126)</i> B. Rabia, N. Kamel, A. Behmounah, Y. Mouheb, S. Kamariz</p> <p>R-C. Begy, Romania <i>Reconstruction of climate variations from Modern Warm Period in Balkan region by using ²¹⁰Pb chronology (276)</i> R-C. Begy, S. Kelemen, J. Nikolov, N. Todorovic, N. Smejčanin, M. Nuhanovic, M. Krmr, D.S. Veres</p> <p>Y. Ji, China <i>Determination of ultra-trace uranium and thorium in six-grade particles (288)</i> Y. Ji, Y. Zhang, X. Shao</p> <p>R. Idoeta, Spain <i>Possibilities of the new scintillation CeBr3 for radiological environmental monitoring (238)</i> R. Idoeta, M. Herranz, N. Alegria, F. Legards</p>	<p>V. Jobbagy, Belgium <i>Performance evaluation of a European scale radon-in-water proficiency test (267)</i> V. Jobbagy, M. Hult</p> <p>I. Krajcar Bronić, Croatia <i>Participation in the international inter-laboratory comparisons study for biogenic component in liquid fuels by the ¹⁴C method (139)</i> I. Krajcar Bronić, J. Kozar Logar, R. Krištof, J. Nikolov, N. Todorović, I. Stojković, J. Barešić, A. Sironić, D. Borković</p> <p>E. Braysher, United Kingdom <i>Development of certified reference materials in support of characterisation of naturally occurring radioactive material (22)</i> E. Braysher, B. Russell, F. Dal Molin, D. Read</p> <p>K. Sobiech-Matura, Belgium <i>Improving emergency preparedness – spiked reference material production and emergency proficiency testing (214)</i> K. Sobiech-Matura, G. Lutter, R. Van Ammel, G. Marissens, M. Hult, H. Emteborg</p> <p>J. Kožar Logar, Slovenia <i>Interlaboratory comparison and OBT measurements in biota in the environment of NPPK (144)</i> R. Krištof, J. Kožar Logar, A. Sironić, I. Krajcar Bronić</p> <p>K. Szewczak, Poland <i>Application biochar into the soil – if it influence for environmental radioactivity? (263)</i> K. Szewczak, S. Jednoróg, K. Wołoszczuk, R. Szlązak, Z. Podgórska, A. Rafalska-Przysucha, M. Łukowski</p> <p>C. Ononugbo, Nigeria <i>Assessment of radionuclides in solid minerals and drinking water from selected mining sites of Benue State, Nigeria (25)</i> C. Ononugbo, G. Avwiri</p> <p>I. Louw, South Africa <i>Promoting technical cooperation among radioanalytical laboratories for the measurement of environmental radioactivity – an International Atomic Energy Agency (IAEA) Technical Cooperation project RAF/7/017 (216)</i> I. Louw, M. Rozmaric, S. Haile</p>
19:00 – 21:00	Prague Sightseeing Walking Tour	



08:30 – 11:00	<p align="center">Plenary Session II [Room Don Giovanni 2-3, 2nd floor] Chair: T.M. Nakanishi, A.J.T. Jull</p>	
<p>08:30 09:00 09:30 10:00 10:30</p>	<p>K. Hirose, Japan <i>Atmospheric impacts of the Fukushima Daiichi NPP accident: a review of eight-years studies in Japan (68)</i></p> <p>M. Aoyama, Japan <i>Mass balance and latest fluxes of radiocaesium and tritium derived from Fukushima accident in the western North Pacific Ocean and coastal regions of Japan (152)</i> M. Aoyama, D. Tsumune, Y. Inomata, J. Tateda</p> <p>Y. Kumamoto, Japan <i>Measurements of low activity concentration of Fukushima-derived radiocaesium in the western subarctic gyre of the North Pacific Ocean in summer 2017 (33)</i> Y. Kumamoto, M. Aoyama, Y. Hamajima, A. Murata</p> <p>S-H. Lee, Korea <i>Radiocaesium contamination in seawater around the Koran Peninsula after Fukushima Nuclear Power Plant accident (245)</i> S.H. Kim, S-H. Lee, G.H. Hong, H.M. Lee</p> <p>N. Yasuda, Japan <i>Lessons learned from the radiological responses to TEPCO-Fukushima Daichi Nuclear Disaster (319)</i> N. Yasuda, H. Fukuo</p>	
11:00 – 11:30	Coffee break	
11:30 – 13:00	<p align="center">Parallel Session 4A Fukushima Impact [Room Don Giovanni 2-3, 2nd floor] Chair: M. Aoyama, G. Steinhauser</p>	<p align="center">Parallel Session 4B NORMS [Room Donna Anna/Donna Elvira, 1st floor] Chair: A. Ioannidou, N. Yasuda</p>
<p>11:30 11:45 12:00 12:15 12:30 12:45</p>	<p>D. Tsumune, Japan <i>Impacts of direct release and riverine discharge on oceanic ¹³⁷Cs derived from the Fukushima Dai-ichi Nuclear Power Plant accident (165)</i> D. Tsumune, T. Tsubono, K. Misumi, M. Hikaru, Y. Tateda, Y. Toyoda, Y. Onda, M. Aoyama</p> <p>J. Kaizer, Slovakia <i>Temporal changes in the tritium and radiocarbon concentration in the western North Pacific Ocean (1993 – 2012) (191)</i> J. Kaizer, Y. Kumamoto, M. Molnár, L. Palcsu, P.P. Povinec</p> <p>Y. Tateda, Japan <i>Reconstruction of temporal change of radiocaesium level in demersal fish off Fukushima (74)</i> Y. Tateda, K. Misumi, D. Tsumune, M. Aoyama, Y. Hamajima, T. Aono</p> <p>R. Kierepko, Poland <i>Heterogeneity of isotopic signatures of the FDNPP in the environmental samples (134)</i></p> <p>A. Shimada, Japan <i>¹³⁵Cs/¹³⁷Cs isotope ratio near the Fukushima Daiichi Nuclear Power Station (77)</i> A. Shimada, T. Tsukahara, M. Nomura, T. Shimada, S. Takeda</p> <p>M-H. Lin, Taiwan <i>Investigation of radioactive cesium level in seawater near Taiwan after the Fukushima nuclear accident (32)</i> P-F. Lee, W-J- Huang, P-J. Huang, M-H. Lin, J-J. Wang</p> <p>R. Garcia-Tenorio, Spain <i>Radioecology in placer deposits: a case study (256)</i> R. Garcia-Tenorio, O. C. Lind, I. Vioque, M. C. Jimenez-Ramos, C. Bañobre, B. Salbu</p> <p>W-H. Wang, USA <i>Investigation of elevated radiation exposure from debris of a renovation project (23)</i> W-H. Wang, A. Hamideh, J. Robinson</p> <p>J. L. Guerrero Márquez, Spain <i>Is there migration of natural radionuclides from the phosphogypsum stacks into the underlying salt-marsh substrate? (151)</i> J. L. Guerrero Márquez, I. Gutiérrez Álvarez, S.M. Pérez Moreno, F. Mosqueda Peña, M. Ollas Álvarez, R. García-Tenorio García-Balmaseda, J.P. Bolivar Raya</p> <p>I. Hupka, Czech Republic <i>Development of in vitro testing methods with materials suitable for radiation exposure and internal contamination assessment including NORM materials (228)</i> I. Hupka, V. Bečková</p> <p>H. Jaegler, France <i>Exploring uranium isotopes (U-233, U-236) as a new tracer to highlight uranium contamination downstream former uranium mine sites (150)</i> A. Gourgjotis, A. Mangeret, P. Blanchart, G. Morin, K. Hain, P. Steier, R. Golser, C. Cazala</p> <p>M.M. Nirwono, Korea <i>Soil air radon concentration in Bintan Island, Indonesia (115)</i> M.M. Nirwono, A.C.Syuryavin, S.J. Park, S.H. Lee</p>	
13:00 – 14:00	Lunch	

14:00 – 15:00	Poster Session 1 [Rooms Don Ottavio/Massetto/Leporello/Zerlina, 1 st floor]	
15:00 – 17:30	Parallel Session 5A Fukushima and Chernobyl Impact [Room Don Giovanni 2-3, 2 nd floor] Chair: P. Bossew, Y. Kumamoto	Parallel Session 5B Recent Developments in Analytical Methods II [Room Donna Anna/Donna Elvira, 1 st floor] Chair: L. Benedik, C. Tsabaris
15:00	J. Igarashi, Japan <i>Identification of plutonium isotopes in radioactive particles released from the Fukushima Daiichi Nuclear Power Plant (153)</i> J. Igarashi, J. Zheng, Z. Zheng, K. Ninomiya, Y. Satou, M. Fukuda, Y. Ni, T. Aono, A. Shinohara	A. Ioannidou, Greece <i>Trace elements and radioactive nuclides studied in the region of Northern Greece using Hypnum cupressiforme Hedw. as biomonitor (121)</i> C. Betsou, E. Tsakiri, K. Eleftheriadis, L. Diapouli, M. Krmar, J. Hansman, M. Frontasyeva, A. Ioannidou
15:15	Y. Suzuki, Japan <i>Transfer of radiocesium from irrigation water to ice (187)</i> Y. Suzuki, T. Iizuka, T. Matsubara, R. Inaba, S. Miyazu, T. Gomei, K. Ito, M. Shin, N. Yoshikawa, N. Nogawa, K. Suzuki, N. Harada	D. Degering, Germany <i>Analysis of tritium on environmental levels in the area of Dresden, Germany (107)</i> D. Degering, M. Kaden, M. Köhler
15:30	S. Fujimura, Japan <i>Estimation of radiocesium concentration in brown rice using the soil exchangeable potassium content and soil radiocesium (201)</i> S. Fujimura, S. Takuro, O. Takeshi, Y. Kohji	M. Vasyanovich, Russia <i>Baromembrane method for analysis of ultra-low concentrations of radionuclides in water sampling (43)</i> M. Vasyanovich, A. Ekidin, A. Trapeznikov, A. Plataev
15:45	E. Reinoso-Maset, Norway <i>Linking heterogeneous distribution to mobility and potential bioavailability for radiocaesium in soils and pond sediments in the Fukushima Daiichi exclusion zone (230)</i> E. Reinoso-Maset, J. Brown, F. Steenhuisen, B. Salbu, O.C. Lind	M. Miecznik, Poland <i>Search for tritium in air in a room equipped with 14 MeV neutron generator with tritiated targets (158)</i> M. Miecznik, J-W. Mietelski, K. Brudecki, A. Wójcik-Garguła
16:00	M. Ivanov, Russia <i>The Chernobyl-derived ¹³⁷Cs accumulation in artificial reservoirs in Central Russia as indicator of sediment sources (200)</i> M. Ivanov, E. Konstantinov, N. Ivanova, A. Tsyplenkov, N. Kuzmenkova, A. Gurinov, A. Konoplev, V. Golosov	B. Feng, China <i>Application of synthetic benzoic acid-7-14C in environmental radiocarbon measurement (67)</i> B. Feng, C. Zhao, B. Chen, W. Zhuo, L. He, F. Tang
16:15	A. Konoplev, Japan <i>Vertical distributions of Chernobyl-derived Cs-137 and Am-241 in bottom sediments of water bodies in exclusion zone represent long-term dynamics of water contamination (95)</i> A. Konoplev, G. Laptev, H. Lisovyi, Y. Igarashi, K. Nanba	L. Song, China <i>Rapid determination of polonium-21 for atmospheric application (215)</i> L. Song, X. Dai
16:30	I. Sekudewicz, Poland <i>Spatial and vertical variability of ¹³⁷Cs activity in lake sediments of two dam lakes in Poland after the Chernobyl fallout (177)</i> I. Sekudewicz, M. Gąsiorowski	X. Dai, China <i>Rapid and sensitive methods for transuranic radionuclides in environmental samples (257)</i> X. Dai, M. Luo, D. Liu, Y. Wu, S. Xing
16:45	N. Nihei, Japan <i>Radiocesium deposition on agricultural products by resuspended matter (141)</i> N. Nihei, T. Nakanishi	G. Yue, China <i>Polyvinyl alcohol (PVA) based porous organic polymers for iodine adsorption and mechanistic aspect (17)</i>
17:00	S.J. Limlingan, Philippines <i>Screening for radionuclide contamination from the Fukushima accident by Iodine-129 measurement in corals from Baler (218)</i> S.J. Limlingan, A. VII Bautista, A. Jagonoy, E. Jr. Dumalagan, F. Siringan, H. Kusuno, H. Matsuzaki	C. Sabbarese, Italy <i>Development and calibration of a method for direct measurement of thoron (277)</i> F. Ambrosino, R. Buompane, V. Roca, C. Sabbarese
17:15		
16:30 – 18:00	Poster Session 1 & Beer [Rooms Don Ottavio/Massetto/Leporello/Zerlina, 1 st floor]	



08:30 – 11:00	<p style="text-align: center;">Plenary Session III [Room Don Giovanni 2-3, 2nd floor] Chair: K. Hirose, X. Hou</p>
08:30	<p>O. Masson, France <i>The European-scale ¹⁰⁶Ru detection event by the Ro5 network (180)</i> O. Masson, G. Steinhauser</p>
09:00	<p>G. Steinhauser, Germany <i>Some speculations and their assessment about the release of radioruthenium in fall 2017 (333)</i></p>
09:30	<p>M. Laubenstein, Italy <i>Ultra-low background gamma-ray spectrometry and its applications (269)</i></p>
10:00	<p>B. Salbu, Norway <i>Radioactive particle released into the environment – recent update (250)</i></p>
10:30	<p>G. Lujanienė, Lithuania <i>Carbon isotopes as tracers of organic and inorganic carbon in Baltic Sea sediments (249)</i></p>
11:00 – 11:30	Coffee break

11:30 – 13:15	Parallel Session 6A Atmosphere [Room Don Giovanni 2-3, 2 nd floor] Chair: O. Masson, M. Molnár	Parallel Session 6B NORMS and Natural Radionuclides [Room Donna Anna/Donna Elvira, 1 st floor] Chair: N. Todorovic, R. Garcia-Tenorio
11:30 11:45 12:00 12:15 12:30 12:45 13:00	<p>P. Bossew, Germany <i>The Ruthenium-106 event, September – October 2017: a cold case (72)</i> P. Bossew, F. Gering, E. Petermann, T. Hamburger, C. Katzlberger, M.A. Hernandez-Ceballos, M. De Cort, K. Gorziewicz, R. Kierepko, J.W. Mieelski</p> <p>J.W. Mietelski, Poland <i>What was behind a mysterious Ru-106 contamination of European air observed in 2017? (109)</i> J.W. Mietelski, P. Povinec</p> <p>D. Zok, Germany <i>Nuclear forensics around the Ruthenium-106 release in fall 2017 above Europe (195)</i> D. Zok, G. Steinhauser, D. Degering, J.H. Sterba, M.W. Cooke, T. Hopp</p> <p>M.K. Pham, Monaco <i>Impact of Saharan dust events on radionuclide levels in Monaco air, in th water column and in sediment cores of the northwestern Mediterranean Sea (21)</i></p> <p>I. Kontul', Slovakia <i>Radiocarbon analysis of carbonaceous aerosols in Bratislava, Slovakia (253)</i> I. Kontul', J. Kaizer, M. Jeřkovský, P. Steier, P.P. Povinec</p> <p>R. Uhlář, Czech Republic <i>Correlations between ⁷Be dry deposition and meteorological data (183)</i> R. Uhlář, P. Haroková, P. Alexa, M. Kačmařík</p> <p>W. Zhang, Canada <i>A study of natural radioactivity accumulation and aerosol mean transit time from their area of origin to the Canadian Arctic region with monitoring data of both radon and thoron progeny (8)</i></p>	<p>D. Heine, Germany <i>Effects of the cement production industry on NORM distribution in Nigeria (282)</i> C. Walther, D. Heine, T. Weissenborn, F. Köhler, O. Ife-Adediran, S. Bister</p> <p>S.M. Pérez Moreno, Spain <i>Radioactive and radiological characterization of Spanish commercial bottled drinking water (155)</i> S.M. Pérez Moreno, J.L. Guerrero Márquez, F. Mosqueda Peña, M.J. Gázquez, J.P. Bolívar Raya</p> <p>M. Capua, Italy <i>Evaluation of the radon mass exhalation rate in Italian tuff using the closed chamber technique (40)</i> J. del C. Orbe Ordoñez, M. Capua, G. Durante, J. Castagna</p> <p>N. Veerasamy, Japan <i>Geochemical behaviour of Uranium and Thorium in soils and sands from a natural background radiation area of Odisha coast, India (69)</i> N. Veerasamy, S. Sahoo, K. Inoue, M. Fukushi</p> <p>M. Adelikhah, Hungary <i>Comprehensive radiological study on water and soil of high natural background area of Dehloran, Iran (209)</i> M. Adelikhah, A. Shahrokhi, A. Peka, T. Kovács</p> <p>A.C. Syuryavin, Korea <i>Influence of humidity to exhalation of Radon and Thoron from building materials, and analysis of their radiological risk in indoor environment (132)</i> A.C. Syuryavin, S.H. Lee M. M. Nirwono</p> <p>J. del C. Orbe Ordoñez, Italy <i>Comparison between measurements techniques of radon concentration in spring water (41)</i> J. del C. Orbe Ordoñez, M. Capua, G. Durante, J. Castagna</p>
13:15 – 14:15	Lunch	
14:15 – 22:00	Conference Trip to Kutná Hora (including dinner)	



08:30 – 11:00	Plenary Session IV [Room Don Giovanni 2-3, 2 nd floor] Chair: A. Chatt, J. Kučera	
08:30	S. Nisi, Italy <i>ICP-MS: radiopure material selection and applications for measurements of radionuclides in the environment (248)</i>	
09:00	X. Hou, Denmark <i>Environmental radioactivity: analysis, distribution and trace studies of long-lived radionuclides (246)</i>	
09:30	A.J.T. Jull, USA <i>Measurements of ¹²⁹I in coastal Pacific Ocean sites in California and US Pacific Northwest sites (320)</i> <i>A.J.T. Jull, C-C. Chang,,G.S. Burr, L. Cheng, J. Russell, A. Priyadarshi, M. Lin, D. Crocker, M. Thiemens, D. Biddulph</i>	
10:00	M. Molnár, Hungary <i>Quantifying fossil carbon load in urban vegetation using C-14 – a case study from Debrecen Hungary (173)</i> <i>M. Molnár, T. Varga, P. Barnucz, I. Major, Z. Lisztes-Szabó, E. László, J. Péntzes, A.J.T. Jull</i>	
10:30	J-W. Mietelski, Mietelski <i>Search for extinct natural radionuclides in kimberlite rock to verify the baryonic dark matter impact hypothesis (110)</i> <i>J-W. Mietelski, R. Anczkiewicz, M. Paszkowski, P. Steier, B. Lahmann</i>	
11:00 – 11:30	Coffee break	
11:30 – 13:00	Parallel Session 7A Impacts of Nuclear Facilities [Room Don Giovanni 2-3, 2 nd floor] Chair: B. Salbu, S. Nisi	Parallel Session 7B MC Modelling [Room Donna Anna/Donna Elvira, 1 st floor] Chair: O.C. Lind, D. Tsumune
11:30	M. Iosjpe, Norway <i>Evaluation of the activity of the high activity particles in the intertidal beach region near the Sellafield nuclear facilities after long-term exposure (161)</i> <i>M. Iosjpe, J. Brown, J.C. Mora Cañadas, J. Smith Justin</i>	D. Ene, Sweden <i>Modelling of environmental processes from ESS releases (36)</i>
11:45	F. Köhler, Germany <i>¹²⁹Iodine in environmental samples: analysis of river and sea water from the vicinity of the Sellafield reprocessing plant and insight into migration behaviour in the soil vadose zone (142)</i> <i>B. Riebe, C. Walther, F. Köhler, N. Molkenthin</i>	N. Alegria, Spain <i>Simulation of the influence of the radium concentration in the soil and radon concentration in air for NaI detector considered in Preparedness Project using MCNP (65)</i> <i>N. Alegria, F. Legarda</i>
12:00	G. Pédehontaa-Hiaa, Sweden <i>Assessment of tritium levels in man in Lund, Sweden, prior to the start of operation of the European Spallation Source (93)</i> <i>G. Pédehontaa-Hiaa, H. Hanna, S. Mattsson, C.L. Rääf, K. Eriksson Stenström</i>	V. Hormann, Germany <i>Modelling the partitioning of Am and Pu in agricultural soils using the geochemical code PHREEQC (71)</i> <i>V. Hormann, H.W. Fischer</i>
12:15	O. Jefanova, Lithuania <i>Initial radioecological and environmental state of Lithuanian transboundary area before the start of the operation of the NPP in Belarus (202)</i> <i>O. Jefanova, I. Baužienė, R. Petrošius, Ž. Skuračovič, D. Bridžiuvienė, L. Levinskaitė, V. Raudonienė, J. Švedienė, A. Paškevičius, G. Lujanienė</i>	V. Palušová, Slovakia <i>Background sources in the Modane underground laboratory (182)</i> <i>V. Palušová, P.P. Povinec R. Breier</i>
12:30	A. Panov, Russia <i>Developing of the radioecological monitoring system of atmospheric air, terrestrial and freshwater ecosystems in the vicinity of Rooppur NPP (People's Republic of Bangladesh) (34)</i> <i>A. Panov, N. Isamov, V. Kuznetsov, D. Kurbakov</i>	R. Breier, Slovakia <i>Monte Carlo simulation of HPGe detectors for radon measurements in the air using Marinelli containers (259)</i> <i>R. Breier, M. Ješkovský, V. Palušová, A. Javorník, J. Ometáková, P.P. Povinec</i>
12:45	I. Byrnes, Norway <i>Characterization of uranium containing particles originating from the Dounreay nuclear reprocessing facility (229)</i> <i>I. Byrnes, O.C. Lind, E. Hansen, P. Dale, C. McGuire, K. Janssens, B. Salbu</i>	E. Bilgic, Turkey <i>Assessment of the impacts of Chernobyl Nuclear Power Plant accident on Turkey using mathematical modelling method (145)</i> <i>E. Bilgic, O. Gunduz</i>
13:00 – 14:00	Lunch	

14:00 – 15:00	Poster Session 2 [Rooms Don Ottavio/Massetto/Leporello/Zerlina, 1 st floor]	
15:00 – 17:00	Parallel Session 8A Radionuclides in Biota [Room Don Giovanni 2-3, 2 nd floor] Chair: M. Clemenza, J. Tateda	Parallel Session 8B Radioecology I [Room Donna Anna/Donna Elvira, 1 st floor] Chair: I. Krajcar Bronic, M. Iosjpe
15:00	T. Zotina , Russia <i>Time-dependent trends of artificial radionuclides in fish, zoobenthos, and aquatic moss of the Yenisei River (Siberia, Russia) (28)</i> T. Zotina, E. Trofimova, D. Dementyev	O. C. Lind , Norway <i>Using AMS for speciation and source identification purposes within environmental radioactivity (270)</i> O.C. Lind, D.H. Oughton, L. Skipperud, H-C. Teien, B. Salbu
15:15	H. Moll , Germany <i>Interaction of curium(III) with plant cells (Brassica napus) (80)</i> H. Moll, S. Sachs, J. Raff	D. Jakab , Hungary <i>Comparative analysis of active and passive dosimetry systems used in environmental gamma radiation monitoring (231)</i> D. Jakab, I. Apáthy, A. Csőke, S. Deme, G. Endrődi, L. Tósaki, T. Pázmándi
15:30	S. Sachs , Germany <i>Uranium toxicity on plant cells: isothermal microcalorimetric studies for the differentiation between chemotoxic and radiotoxic effects of uranium (81)</i> S. Sachs, J. Oertel, K. Fahmy	A. Azbouche , Algeria <i>Use of ¹³⁷Cs and ²¹⁰Pb to assess soil redistribution in a cultivated site in wester Algeria (167)</i> A. Azbouche, B. Morsli, E. Fulajtar, S. Gouasmia, F. Gacem, F. Boussahoul, Z. Melzi
15:45	A. Heller , Germany <i>Effect of trivalent lanthanides and actinides on a rat kidney cell line (87)</i> A. Heller, M. Acker, A. Barkleit, F. Bok, J. Wober	L. Khumalo , Hungary <i>Mobility of radionuclides from the spoil deposit No. 1 of the abandoned uranium mine in Pécs, Hungary (89)</i> L. Khumalo, G. Heltai, M. Horváth
16:00	D. Tatarová , Slovakia <i>Removal of selected gamma and alpha radionuclides from aquatic solutions using Chlamydomonas reinhardtii, Scenedesmus obliquus and Chlorella vulgaris (184)</i> D. Tatarová, D. Galanda, J. Kuruc, B. Gaálová	M. Hamideen , Jordan <i>Contribution of environmental radionuclides to radiological hazard effects due to surface soils collected from Amman Governorate, Jordan (125)</i>
16:15	V. Hansen , Denmark <i>²¹⁰Po bioaccumulation in Arctic seabirds (261)</i> V. Hansen, A. Mosbech, F.R. Merkel, G. Asmund, F. Rigét, J. Søgaard-Hansen, I. Eulaers	J. Schick , France <i>Chabazite, a promising zeolite material for radium removal from mining water (91)</i> J. Schick, V. Luquet de Saint-Germain
16:30	R. Nayak , India <i>Determination of water equivalent factor (WEQp) for evaluation of organically bound tritium in environmental matrices (241)</i> R. Nayak, R.S. D'Souza, Srinivas S. Kamath, Bharath S., Narayana B., Dileep B.N., Ravi P.M., K. Naregundi	X. Zhao , China <i>^{239,240}Pu and ¹³⁷Cs in soils from Northern Xinjiang: the closest downwind area from Semipalatinsk nuclear test site in China (178)</i> JX. Zhao, J. Qiao, X. Hou, P. Roos, Y. Wang
16:45	B.H. Fawaris , Libya <i>Impact of NORM/TE-NORM on safety of workers and surrounding environment in Libyan oil and gas production fields (287)</i>	F. Legarda , Spain <i>Radon activity concentration assessment in Pozalagua Cave (234)</i> S. Rozas, N. Alegría, R. Idoeta, M. Herranz, F. Legarda
17:00 – 18:00	Poster Session 2 & Beer [Rooms Don Ottavio/Massetto/Leporello/Zerlina, 1 st floor]	
20:00 – 23:00	Gala dinner	



08:30 – 10:30	<p style="text-align: center;">Plenary Session V [Room Don Giovanni 2-3, 2nd floor] Chair: M. García-León, J. John</p>
08:30	<p>J. Kučera, Czech Republic <i>Atom counting of long-lived radionuclides using neutron activation analysis (221)</i> <i>J. Kučera, J. Kamínk, P.P. Povinec, I. Krausová, I. Světlík</i></p>
09:00	<p>M. Clemenza, Italy <i>Low background neutron activation: a high sensitivity technique for long-lived radionuclides determination in rare events physics experiments (294)</i></p>
09:30	<p>A. Chatt, Canada <i>Determination of low levels of ²³⁸U and ²³²Th with low expanded uncertainties in water and foods using instrumental, preconcentration and radiochemical neutron activation analysis (288)</i> <i>S. Hevia, A. Chatt</i></p>
10:00	<p>V. Wagner, Czech Republic <i>Czech power industry in the European context (284)</i></p>
10:30 – 11:00	Coffee break

11:00 – 12:45	Parallel Session 9A Radioecology II [Room Don Giovanni 2-3, 2 nd floor] Chair: J-W. Mietelski, V. Wagner	Parallel Session 9B Radiochemistry [Room Donna Anna/Donna Elvira, 1 st floor] Chair: G. Wallner, M. Němec
11:00 11:15 11:30 11:45 12:00 12:15 12:30	<p>R. Froeschl, Switzerland <i>A radiological data library for environmental impact assessments of accelerator facilities (29)</i> R. Froeschl, P. Vojtyla</p> <p>C. Mothersill, Canada <i>Towards a holistic approach to protection of inhabitants of contaminated environments: the role of non-targeted effects (38)</i> C. Mothersill, C. Seymour</p> <p>H. Saleh, Jordan <i>Exposure build-up factor studies of biological matrices in photon energies 0.05 to 3 MeV (64)</i></p> <p>F. Malacrida, Switzerland <i>Environmental monitoring at CERN (49)</i></p> <p>T. Sojakka, Finland <i>Environmental radioactivity baseline study for disposal facilities (295)</i></p> <p>N. Larionova, Kazakhstan <i>Artificial radionuclides in plants of steppe and forest ecosystems long after nuclear tests at Semipalatinsk test site (120)</i> A. Aidarkhanov, A. Ivanova, N. Larionova, V. Polevik, Y. Shevchenko</p> <p>O. Belyaeva, Armenia <i>Urban geochemical survey as a tool for environmental radioactivity measurements and human health risk assessment (99)</i> O. Belyaeva, K. Pyusyulyan, S. Lilit, N. Movsiyan</p>	<p>M. Tsutomu, Japan <i>Evaluation of radiochemical analysis method for ²¹⁰Po and ²¹⁰Pb in seafood sample using interlaboratory comparison (51)</i> M. Tsutomu, O. Tomoko, T. Hiroshi</p> <p>P. Zhao, China <i>Nanoscale zero-valent iron encapsulated in two-dimensional titanium carbides for removal of Cr(VI): a model for radioactive metal-oxo adsorption (16)</i></p> <p>M. Hegedűs, Japan <i>Caesium retention characteristics of KNiFC-PAN resin from river water (135)</i> M. Hegedűs, H. Tazoe, G. Yang, M. Hosoda, N. Akata, S. Tokonami</p> <p>C-T. Yang, China <i>The separation of AmIII from CmIII with pyridine-type chromatographic material (11)</i> C-T. Yang, H-Z. Yu, X-L. Wang</p> <p>J. Wen, China <i>Phosphorylcholine compounds as chemosensors for recognition of UO₂²⁺ and selective adsorption of uranyl (12)</i></p> <p>N. Wang, China <i>Selective separation of cerium(III) by sodium bismuthate nano-sheets (10)</i> N. Wang, C-T. Yang, S. Hu</p> <p>N. Imam, Egypt <i>Follow up the leaching efficiency of uranium series from high-grade granite sample with high concentration of sulfuric acid (5)</i> A. Nada, N. Imam, A. Ghanem</p>
12:45 – 13:15	<p style="text-align: center;">Plenary Session VI [Room Don Giovanni 2-3, 2nd floor] Chair: P.P. Povinec, I. Světlík</p>	
12:45	<p>F. Brechignac, France <i>An ecosystem approach is mandatory to properly assess ecological risk from radiation (264)</i></p>	
13:15 – 13:30	<p style="text-align: center;">Closing Ceremony [Room Don Giovanni 2-3, 2nd floor] <i>Student award for the best oral and poster presentation</i> ENVIRA 2021</p>	

