

出國報告（出國類別：開會）

參加第 4 屆國際輻射防護委員會(ICRP) 研討會

服務機關：行政院原子能委員會輻射偵測中心

姓名職稱：方鈞屹 技士

派赴國家：法國

出國期間：106 年 10 月 8 日至 106 年 10 月 14 日

報告日期：107 年 1 月 8 日

一、摘要

本次奉派參加國際輻射防護委員會(ICRP)在法國巴黎主辦第4屆年會，由地主國法國核能及輻射防護管制單位 IRSN 主辦，會議地點選於新港灣俱樂部會議中心(Newport Bay Club Convention Center)舉行，會議為期3天。本次會議ICRP與歐盟輻射防護5個研究平台共同舉辦，研究平台包含1.歐洲輻射生態聯盟(ALLIANCE)、2.歐洲輻射劑量組織(EURADOS)、3.歐洲醫學輻射防護研究聯盟(EURAMED)、4.歐洲低劑量輻射風險研究 (MELODI)及5.歐洲核能與輻射緊急應變研究平台(NERIS)；會議主題則搭配各平台研究成果進行發表，EURADOS：劑量轉換因子新進展、MELODI：低劑量與低劑量率輻射生物效應、EURAMED：放射性治療最新發展、NERIS：核災後復原，及 ALLIANCE：整合群眾與環境輻射防護計畫。此會議適逢第2屆歐盟輻射防護研究週(European Radiological Protection Research Week, ERPW)，其對應研究成果共發表14場討論會議，包含眼球劑量評估新發展，多射源場中劑量評估，核災放射性碘曝露劑量重建及監測方法、核災後生物圈之影響、放射診斷及核醫藥物運用之風險與效益及民眾參與環境輻射偵測實務經驗等，議題內容十分廣泛，相對主題會議更講究細項研究成果討論，參與者可依興趣選擇參加。總結3天會議，藉參加現行輻射偵測工作領域分項討論會，獲取最新發展技術資訊，另可瞭解輻射防護系統最新發展趨勢，作為國內未來相關作業參考依據。

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三、 目的

國際輻射防護委員會（International Commission on Radiological Protection:ICRP）係研究輻射對人體的傷害以及提出忠告和相關預防措施的非營利國際學術組織，不定期出版相關技術研究報告及輻射防護安全導則。世界上許多國家依據 ICRP 的建議制定與輻射防護相關的法規。研討會議兩年一期，本次研討會主題如下，低劑量與低劑量率的輻射風險效益及危害；劑量轉換因子的最新研究發展；造影及放射治療的輻射防護演進；核及輻射事故後復原；民眾及環境輻射防護行動整合措施；輻射應用於生物學、流行病學、劑量學、醫學、緊急應變等最新技術發展；及歐盟委員會決議輻射研究政策導向。參與本次會議，著重與環境輻射偵測相關之議題，獲得最新輻射防護觀念，與現行線性無閾值(LNT)機率效應保守模式是否有不同，據此了解國際輻射防護法規對於民眾與環境輻射防護新趨勢。

四、 行程

時間	地點	工作內容
10 月 8 日(日)	高雄→法國巴黎	去程
10 月 9 日(一)	抵達法國巴黎	去程
10 月 10 日(二)~ 10 月 12 日(四)	法國巴黎	參加第 4 屆國際輻射 防護委員會(ICRP)研 討會
10 月 13 日(五)	法國巴黎→高雄	回程
10 月 14 日(六)	抵達高雄	回程

五、 會議過程紀要

第 4 屆國際輻射防護委員會於法國巴黎新港灣俱樂部(Newport Bay Club Convention Center) 會議中心舉行，如圖 1，正式議程為 10 月 10 日至 10 月 12 日，期間與歐盟 5 個輻射防護研究平台共同舉辦，同時安排歐盟輻射防護研究週(ERPW)14 場分項細部研討會。本次主要參與開幕會議、5 項正式議程、6 場分項細部研討會 15 篇口頭論文發表場次及海報成果展示。茲針對參與會議過程紀要如下：



圖 1. 第 4 屆國際輻射防護委員會舉辦會場

(一)、 開幕大會

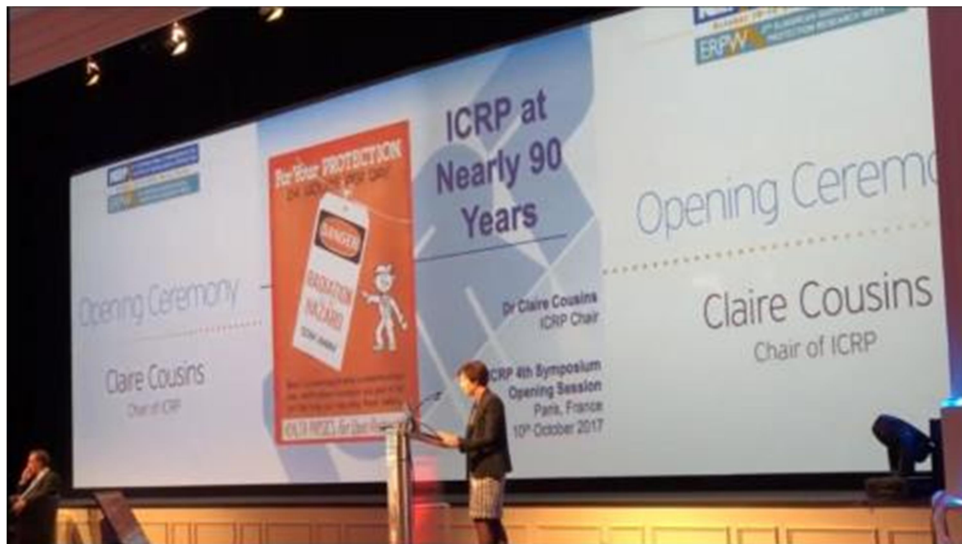


圖 2. ICRP 主席 Claire Cousins 開幕會議致詞

開幕後第一篇報告由國際輻射防護委員會主席 Claire Cousins 介紹 ICRP 運作與宗旨如圖 2，該會 1928 年於英國成立，將近 90 年的歷史，目標為預防因輻射曝露引起

癌症或其他疾病，並提倡輻射運用時應有環境保護責任，並明確定義其研究倫理規範 (Code of Ethics)：1.追求公眾利益(Committed to public benefit)、2.獨立研究(Independent)、3.公正(Impartial)、4.透明資訊(Transparent)與 5.可究責的(Accountable)，並根據聯合國原子輻射影響科學委員會(UNSCEAR)、游離輻射生物效應諮詢委員會或其他研究機構以當前最新輻射曝露效應科學技術研究成果，提供各方面輻射防護因應作為之規劃建議，以建議報告方式發表，至今共計 136 份，其建議報告後續由國際原子能總署(IAEA)、世界衛生組織(WHO)、歐盟(EU)及工業標準(ISO)等單位，制定輻射防護管制安全標準或輻射量測工業標準，最終則由各國輻射防護及核能安全管理單位訂立具法律效應之行動準則如圖 3 所示。

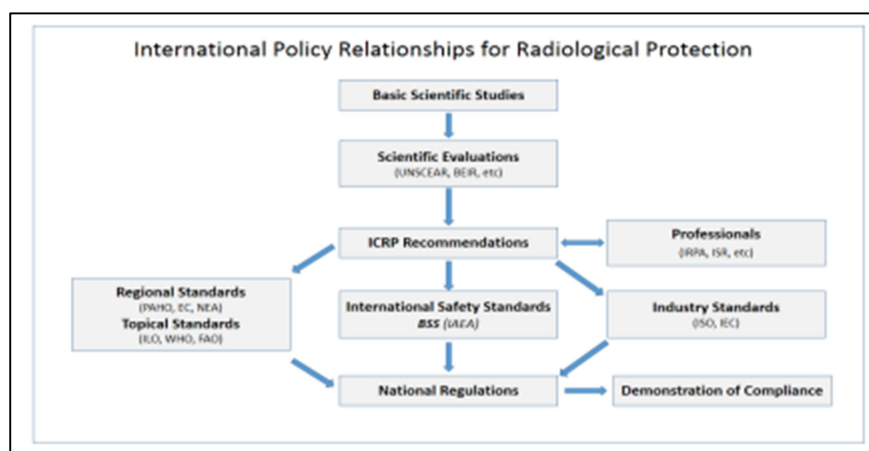


圖 3. 國際輻射防護政策制定流程



圖 4. OECD 之核子能源署主席(NEA)Bill Magwood 開幕會議致詞

第二場報告由經濟合作暨發展組織(OECD)之核子能源署(Nuclear Energy Agency，

NEA)主席 Bill Magwood 以「Radiological Protection: Old Questions Needing New Answers」為題發表如圖 4，說明 NEA 為核能科技應用跨國組織，至 2017 年底，共有 33 個會員國加入，佔世界運用核能技術國家 9 成以上，扮演各國間核能資訊共享橫向連結角色，並強調與 ICRP 之長久合作關係。報告所提舊問題是低劑量與低劑量率之輻射生物效應之研究，其低限劑量 50 毫西弗之管制標準推行已有數年歷史，但探求其代表輻射風險及該數值代表誤差則在科學探討上仍未有明確定義，尤其關於線性無閾模式 (Linear-Non-Threshold, LNT) 長久以來是輻射防護主流觀念，然而在輻射防護法規執行層面與民眾溝通上，就必須考量輻射必定帶來風險之觀念。因此 Magwood 以圖 5 為例，說明 NEA 參與 ICRP 於日本福島核災後舉辦與受災民眾 16 次座談會之經驗，決策單位與民眾溝通時可以藉由公眾關心議題、經濟影響及生活文化等 3 個面向切入討論，但輻射防護(RP)專家常面臨「輻射機率效應」與「致癌風險溝通」的窘境，強調 LNT 模式於低劑量及低劑量率輻射生物效應是否合適仍待更多新的研究成果驗證。

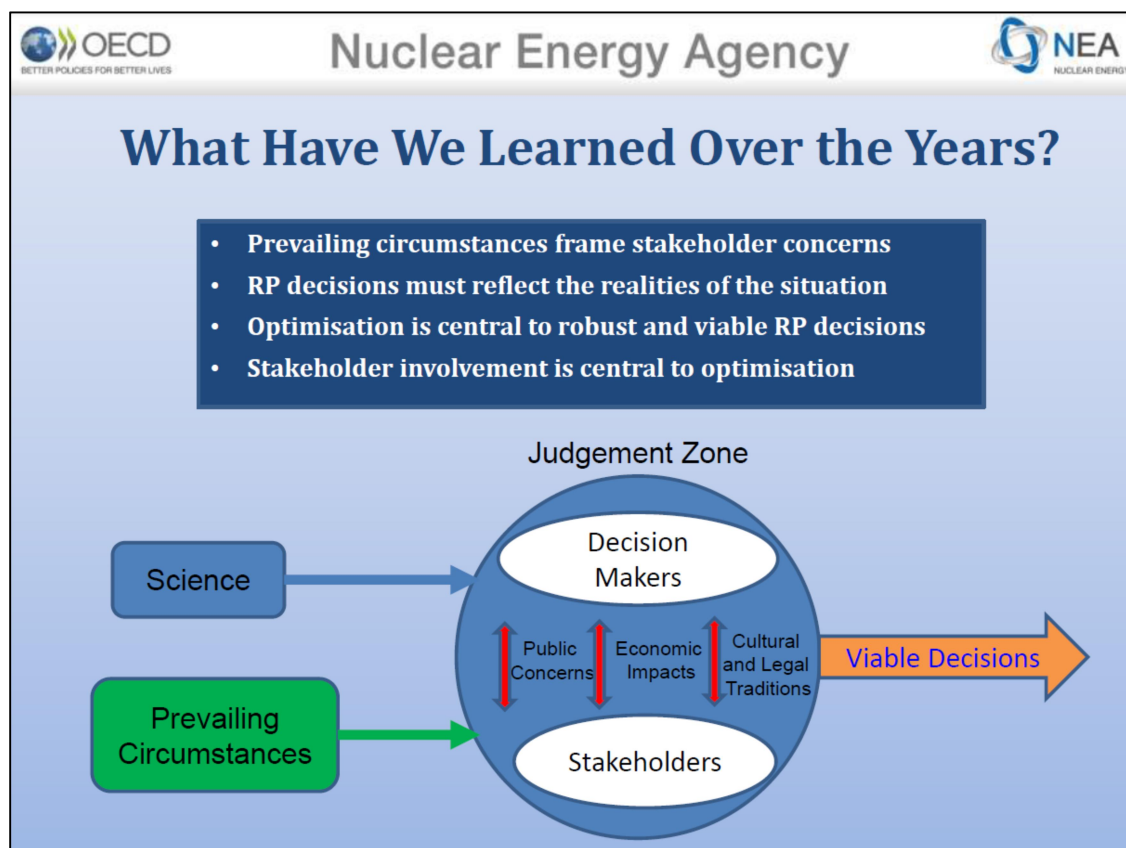


圖 5. NEA 提倡決策單位與公眾之互動關係

(二)、 輻射劑量轉換因子新發展(Advances in Dose Coefficients)主題會議

接續開幕大會後首場主題會議由國際輻射防護委員會第 2 分會(committee 2)與歐洲輻射劑量組織(EURADOS)共同主持，會議中共發表 6 篇口頭報告，其中由德國輻射科學防護研究機構(German Research Center for Environmental Health, GmbH) Maria Zankl 博士說明國際上輻射防護劑量單位訂立原則，如圖 6 所示，闡述由吸收劑量或克馬或通量率分別規劃人員輻射防護之組織等價、吸收劑量及有效劑量或作業場所輻射防護之周圍等效劑量、定向等效劑量及個人等效劑量等項目，分別由不同假體(人形假體或球狀、板型及柱狀假體)評估遭受之輻射劑量，其中劑量轉換因子則可方便運用於前述各項劑量評估，並可藉由監測工作場所輻射劑量，達成管制人員輻射防護劑量標準。

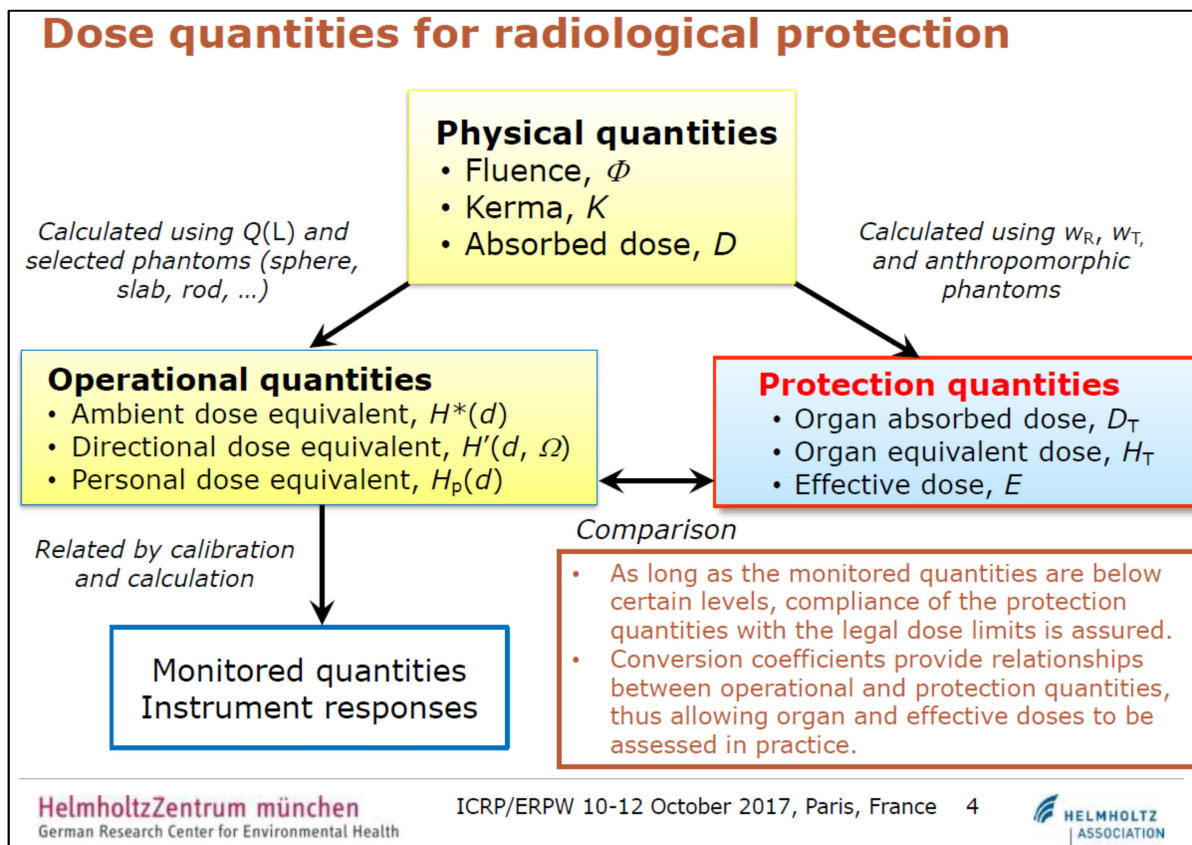


圖 6. 現行各項輻射防護劑量單位定義與關係

此外，由韓國首爾漢陽大學 Chan Hyeong Kim 教授提出關於人形假體模擬技術演進，由 2002 年簡單幾何構型到 2008 年 voxel 模型至最新 polygon mesh 模型，如圖 7，成功提升假體模擬解析度，精準定義微小器官的形狀、位置與重量，可更精準的評估

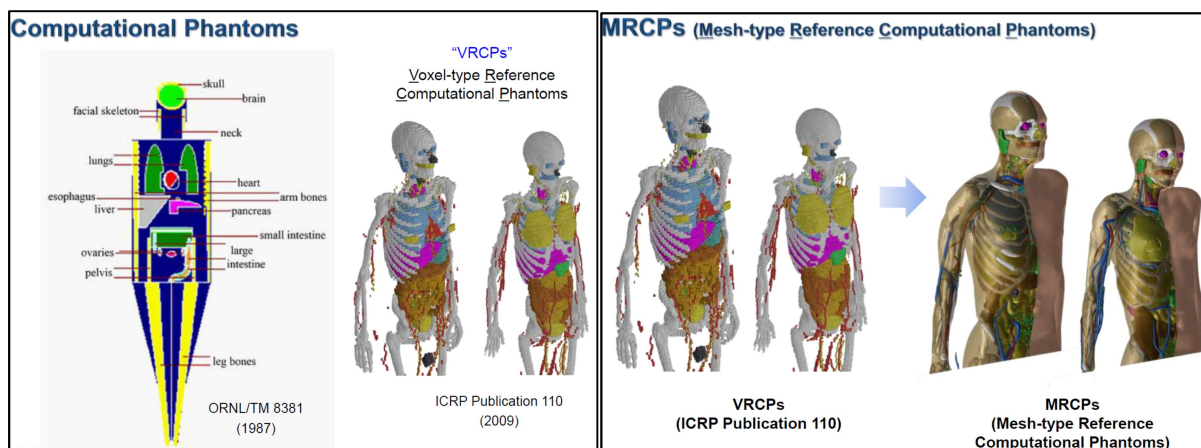


圖 7. 人形假體模擬技術更新示意圖

輻射劑量貢獻。最為顯著影響則是對於電子或阿發粒子等弱穿輻射淺部劑量評估，例如皮膚劑量、眼球劑量及核種射入後呼吸系統支氣管表面劑量評估更為準確如圖 8，新研究成果、更新後劑量轉換因子預定於 2019 年 ICRP 報告中呈現。

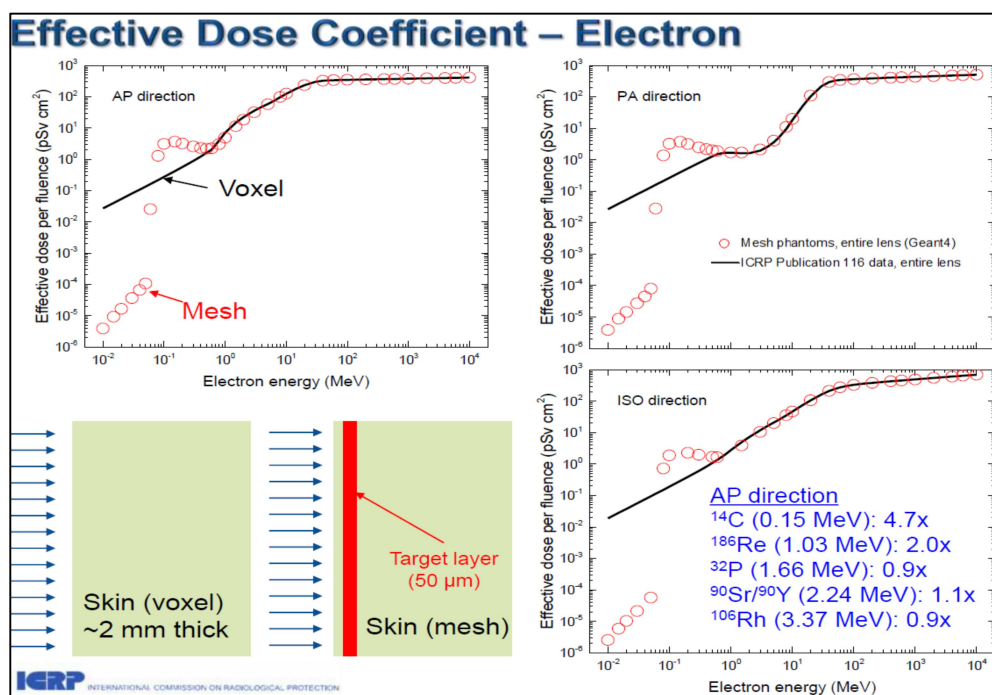


圖 8. polygon mesh 模擬人形假體於淺部劑量貢獻之研究成果

該項主題會議另一項重要議題則由法國核能及輻射防護管制單位(IRS) François Paquet 博士主講體內劑量轉換因子(Internal Dose Coefficients)最新發展，現行 ICRP 對於體內劑量評估方法仍採用生物動力學(biokinetic)與劑量學(dosimetric)模式，強調核種於攝入、吸入及於血液循環系統傳輸過程中所造成的劑量貢獻，其分析方法評估流程如圖 9 所示，而複雜生物分析過程及劑量轉換評估方法將仰賴相關專家分析才可得。

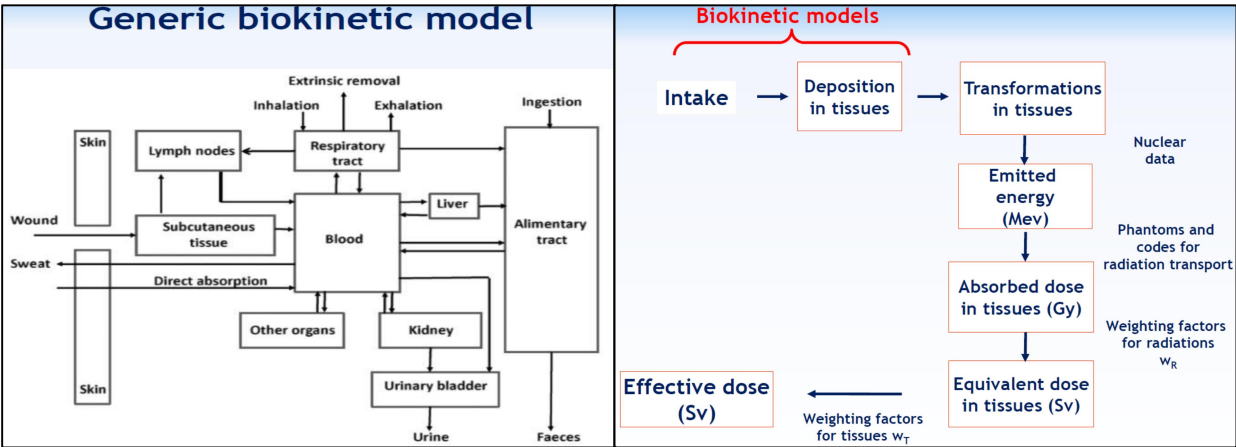


圖 9. ICRP 體內劑量評估分析方法

因此，ICRP 提倡簡化分析流程，設計以 DPIC (Dose per intake coefficient)及 DPC (Dose per content function)兩項參數，依據核種體內劑量長時間累積新研究成果資料庫制定表格，查詢對應劑量轉換因子即可，如圖 10。此外對於新版體內核種傳輸及器官分布模式，將提出體內劑量轉換因子數值，更新後劑量轉換因子於 ICRP134 號及後續 137 號報告中提出。

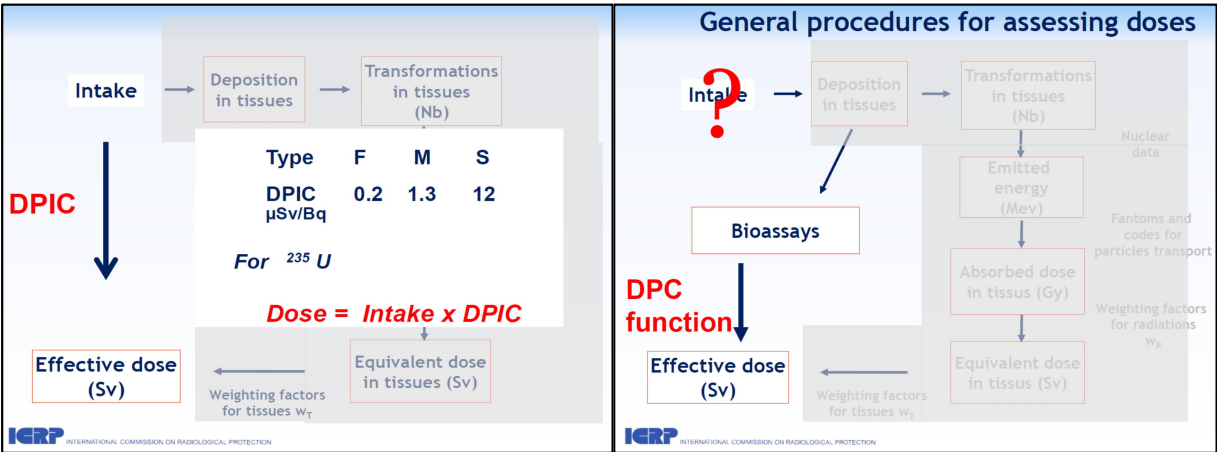


圖 10. ICRP 體內劑量評估 DPIC 及 DPC 分析方法

報告最終則提出 1994 年 ICRP 68 號報告與 2016 年 ICRP134 號報告及未來即將發行 2018 年 ICRP137 號報告內體內劑量轉換因子比較圖，轉換因子並無太大誤差變化，顯示現行體內劑量評估方法仍有效，如圖 11，僅須更新使用最新轉換因子。

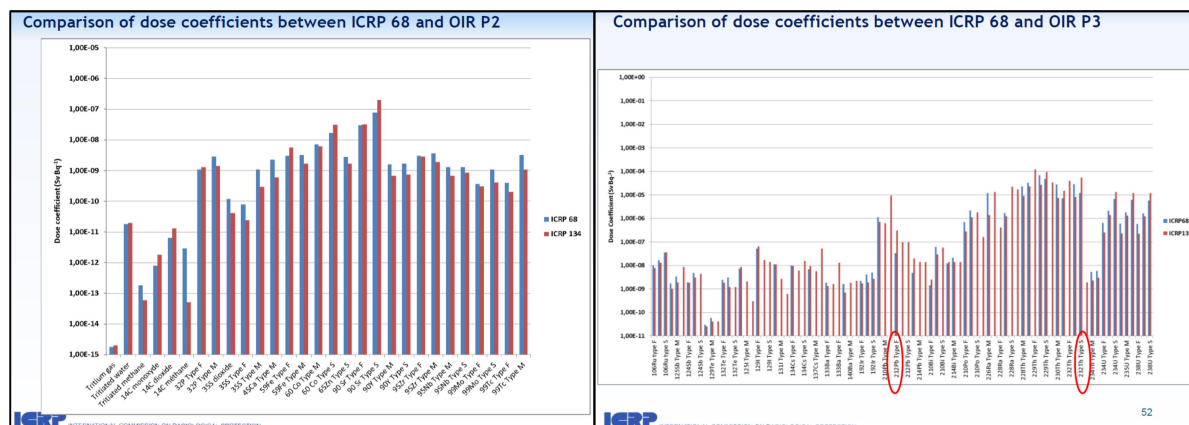


圖 11. ICRP 體內劑量轉換因子 68、134 及 137 號報告比較圖

(三)、 低劑量及低劑量率效應、風險及危害(Effects, Risks, and Detriment at Low Dose and Low Dose-Rate)主題會議

本項主題由 ICRP 第 1 分會(committee 1)與歐洲低劑量輻射風險研究(MELODI)共同主持，共發表 6 篇報告，當中由 ICRP 第 1 分會主席 Helmholtz Zentrum 博士說明最新研究動向包括兒科電腦斷層的致癌風險評估、阿發射源曝露的致癌風險及未來推動人類以外之生物圈(non-human biota)之低劑量輻射機率效應之研究；而 MELODI 主席則說明歐聯在低劑量風險評估研究上，官方 EURATOM 聯合歐盟各研究平台，藉召開發展策略議程(Strategic Research Agenda)參照現今大眾專注議題項目，妥善分配研究經費，其合作效益將由各研究平台大資料庫共享開始，最終使低劑量風險研究成果可推行至各項輻射防護領域，如低限劑量、核災應變範圍訂立及風險溝通如圖 12。

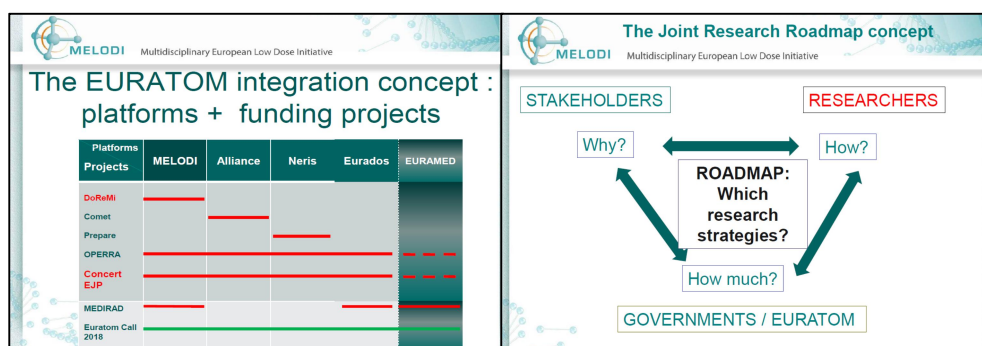


圖 12. 歐盟輻射防護研究橫向連結研究平台架構

此主題中美國國家衛生研究院(National Institutes of Health, NIH) Mark P. Little 博士以動物與人劑量與劑量率效應研究(Evidence for Dose and Dose-rate Effects in Human and Animal Radiation Studies)為題，報告關於低劑量輻射風險及線性無閾假設最新研究成果，指出依據長崎和廣島核爆倖存者劑量回應與致癌機率為 $F(D) = \alpha D + \beta D^2$ with $\alpha > 0$, $\beta > 0$ D 為劑量，此模式適用於於高劑量率至 0.1 西弗致癌風險評估，但對於自高劑量率確定效應延伸至低劑量或低劑量率之致癌風險評估方法，多採用線性外推(Linear extrapolation)如圖 13，而眾多研究顯示不同種類癌症所呈現劑量回應曲線曲率(curvature)將有圖面上 A、B 及 C 三種情況，例如血癌及皮膚癌其劑量回應曲線如 A 曲線、骨癌則傾向 C 曲線，並以 LDEF(low dose extrapolation factor)、DREF(dose rate extrapolation factor)或 DDREF(Dose and Dose Rate Effectiveness Factor)定量表示曲率。

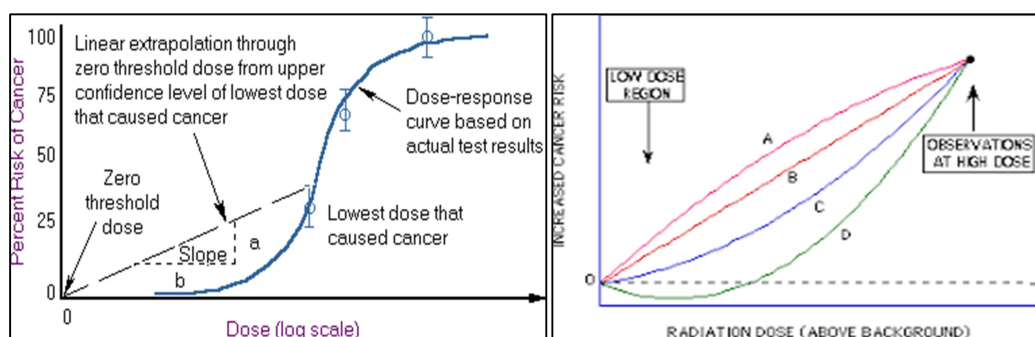


圖 13.輻射低劑量回應效應與致癌風險分析模式

值得注意的是，1970 年至 1992 年於美國阿岡諾實驗室 JANUS 反應器針對 36,735 件老鼠生物體進行低劑量加馬或中子照射實驗，相較於 ICRP(1990,2007)及國際輻射生物效應委員會(Committee on the Biological Effects of Ionizing Radiation, BEIR) 建議報告，新研究結果顯示在劑量率 5mGy/h 之定義下，其對應致癌風險或組織器官功能損傷機率並無明顯增加，且說明以往過度保守(over-estimated)之評估方法，如圖 14。

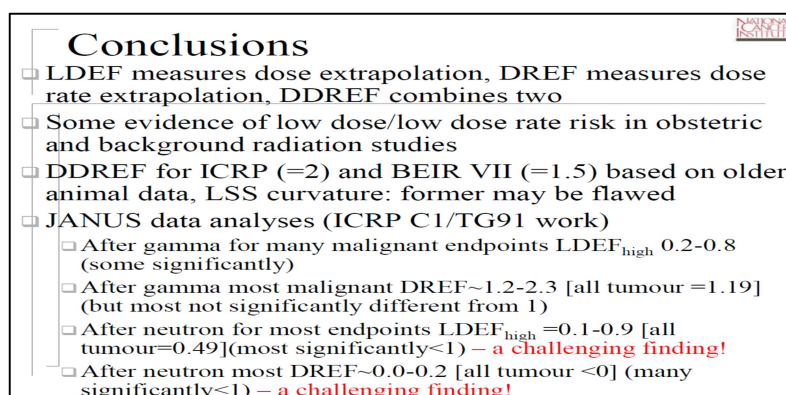


圖 14. JANUS 輻射低劑量回應效應與致癌風險實驗總結

(四)、海報成果展

此次研討會海報成果展安排於會議中心地下 1 樓展示大廳，如圖 15、16，此次海報展示主題配合歐盟輻射防護研究週(ERPW)14 個分項議題，總計 156 篇報告，主題

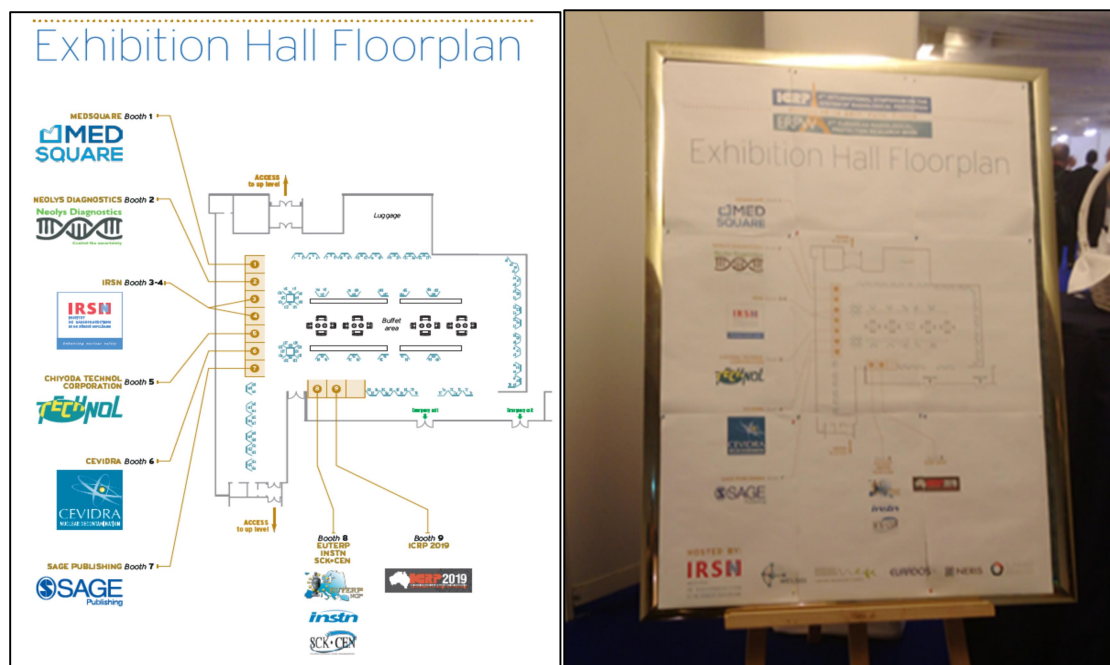


圖 15. 第 4 屆國際輻射防護委員會(ICRP)研討會海報展示區

範圍十分廣泛，包含輻射防護系統道德(Ethic)標準、緊急應變及核災後疏散區與救災決策最佳化、輻射生態學(Radioecology)、診斷及介入性診療放射醫學輻射效益、體內劑量、低劑量率機率效應生物標誌(Bio-maker)方法研究成果、眼球曝露劑量評估、混合輻射場中輻射劑量等。現場除安排海報靜態展示外，作者亦在現場可直接進行技術諮詢與討論；另會場亦安排 8 個合作研究機構攤位，提供技術服務諮詢。



圖 16. 海報展示區現場

(五)、 歐盟輻射防護研究週(ERPW)分項會議

10 月 10 至 12 日於會議期間，除前述 ICRP 與歐盟研究平台共同主持之主題會議外，併同歐盟輻射防護研究成果發表年度會議週，廣泛邀請各不同領域最新研究成果，以分項會議方式口頭發表，主題包羅萬象涵蓋輻射防護各個領域，且分項會議與主題會議同時進行，與會者必需先自行篩選感興趣的場次參加，茲就本次參與 5 個分項會議心得摘述如下：

● 主題 1. 福島核災後緊急應變疏散教訓與因應作為：

此項議題由日本原子力規制委員會(Nuclear Regulation Authority) Nobuhiko Ban 博士提出報告，雖然強調此項報告不代表該國核管單位正式立場，但其報告內容則確實反應福島核災後，日本國內對於核災緊急應變改進作為。首先說明原設計的輻射擴散分析模式在福島核災經驗中無法預測運行，許多防護行動則仰賴電廠中機組實際狀況來決定，因此疏散圈由 10 公里、20 公里至 30 公里及掩蔽等防護行動命令，反覆多次下達之混亂狀況。此外執行核災時疏散計畫，未事先考量各種因素，導致疏散行動窒礙難行；看護之家、獨居老人或疏散範圍內之醫療院所住院病人等相對行動力較差之居民，尤其以醫院急需特殊維生醫療之民眾，因疏散而導致死亡。因此日本已修正緊急應變計畫，回應國際原子能總署所提出之操作干預基準(Operational Intervention Levels, 簡稱 OIL)方法，強調依現場量測輻射劑量率及反應器機組實際狀況作為決策依據，確實推行預防性疏散區(PAZ)及緊急應變區(UPZ)事先規劃，規劃內容則加入醫院病患、年幼者、孕婦，老人及行動不便者、疏散工具及可行路線等細項，加強模擬各項問題之情境，並建立良好溝通模式與公信力，避免疏散時慌亂之情況，如圖 17。

Lessons Learned (Reprise) 18	Conclusions 20
■ Precautionary evacuation on the basis of plant conditions is effective to avert doses. ■ Special consideration should be given to vulnerable people. ■ Unforeseeable situation brings turmoil. ■ Fear of radiation can provoke excessive responses. ■ Lengthy evacuation (temporary relocation) deteriorates people's lives.	■ Precautionary evacuation on the basis of plant conditions is an effective measure to avert doses. ■ Evacuation has a disruptive or destructive influence unless carefully managed. ■ Optimizing the strategy requires consideration of a wide spectrum of potential consequences. ■ Good communication and trust in the authority will be the key to steady implementation of protective measures.

圖 17. 福島核災後日本緊急應變經驗與改善措施方向

● 主題 2 公民參與緊急應變環境輻射量測利與弊之探討

此項議題由捷克國家輻射防護機構(National Radiation Protection Institute, SURO) Petr Kuca 博士說明捷克推動公民參與環境輻射量測之經驗分享。以車諾比及福島核災經驗來說，民眾參與緊急應變與災後復原行動決策，可建立對於管制單位之信心。而參與方式可藉由推行參與環境輻射量測開始，政府單位於平時開發低成本且認證輻射偵測儀器，鼓勵或實質補助民眾購買，同時比對民眾坊間自行購入儀器之偵測結果，並強調所偵測數據，即時傳輸至公開網路平台，平台的建構由政府出資建立，而例行運作維護則委由第三方單位辦理，其中定期舉辦政府、民眾與維運單位技術討論會，可減少彼此技術認知上的隔閡，增加互動互信。以捷克經驗來說，管制單位 SURO 安排 RAMESIS 研究計畫，發展簡易且易操作攜帶之蓋格偵檢器(bGeigie nano)，結合 GPS 地理定位即無線傳輸功能如圖 18，至今若境內需進行道路偵測，已佈放至少 300 個偵檢器予民眾及團體於 1 天之內即可完成；報告最終則明確說明公民參與措施之利與弊，弊：1.民眾以制式儀器取得的初步原始劑量率數值，部分偏高或不合理偵測結果，如地質環境變化，核電廠外釋惰性氣體排放等因素，造成之偏差則須由專家與民眾共同討論解說、2. 在與專家討論偵測結果的誤判，引發不必要的心理恐慌、3.強調公眾參與討論，意謂應變決策耗時且不符時間效益及 4.雙方信心建立過程中，誰具有「專家」資格足以取信雙方。利：1.緊急應變時，民眾參與將匯入大量偵測數據，提升應變決策之時效性、2.平時參與輻射偵測之民眾，可累積相當專業技能與知識，對於管制單位應變作為決策之信心及融入應變體系有實質的助益，3.面臨複合性災害電力喪失時，民眾機動性偵測數據將輔助固定式監測站，在監測站備援電力耗盡後，能接續提供輻射偵測數據。

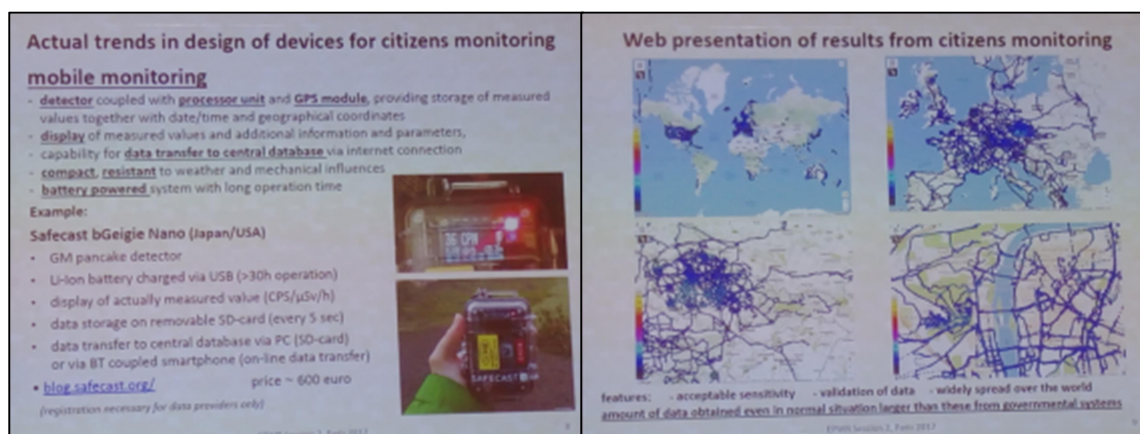


圖 18. 民眾參與輻射偵測設備與數據展示網頁平台

● 主題 3 核災後民眾決定重返疏散區內家園之科學依據

由廣島大學原爆放射醫學研究所保田浩志博士(Dr.Hiroshi Yasuda)報告日本福島核災後，復原措施已容許部分災民返回家園，但依實際經驗顯示民眾決定返回家園時，常對於管制單位專業說詞所困惑，例如公眾 1 毫西弗年劑量限值、ICRP 建議核災後第 1 年 100 毫西弗之劑量限值及工作人員年平均 20 毫西弗等眾多說法，而民眾所關心的是對於婦女及孩童等關鍵群體輻射防護劑量限值，且管制單位必須以更進階、可被理解量化指標，如圖 19，例如以當地劑量量測結果轉換為癌症風險增加機率來說明，因此日本在解除管制區，鼓勵民眾重返家園及對應增加致癌風險的研究中，假定現場環境年劑量為 20 毫戈雷，其沉積於土壤中之銻 134、137，所造成輻射致癌風險提高約為 0.9% 及 2.4%；另假定現場環境年劑量為 5 毫戈雷，則造成輻射致癌風險提高約為 0.2% 及 0.4%，因此管制單位在平時即須建立對應數值資料庫，供應變及民眾決策使用。

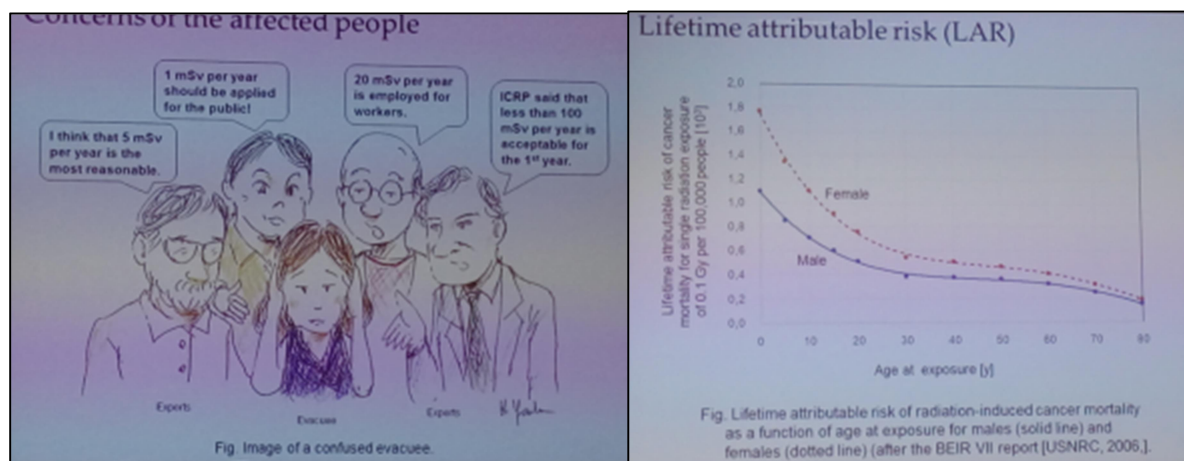


圖 19. 災後管制區域解禁民眾關切之議題與溝通技巧

● 主題 4 核災後兒童與成人甲狀腺劑量評估與監測方法建立

由法國核能管制單位(IRSIN) David Broggio 提出「Child and Adult Thyroid Monitoring After Reactor Accident, CAThyMARA」計畫成果，該計畫考量核災初期氣化碘 131 外釋擴散人體吸收累積於甲狀腺，為主要劑量貢獻之來源，因此由歐盟輻射防護機構提供研究資金，會集 13 個歐洲研究機構共 43 專家於 2017 年發表技術指引報告：Technical guidelines for radio-iodine in thyroid monitoring，報告內容包括甲狀腺體外劑量偵檢器之選擇如圖 20、建立校正與量測地點、量測時間方法，量測結果誤差分析如圖 21；此外對於民眾參與量測亦提出專家建議如圖 22；許多研究成果將共享於歐盟各會員國，並開放下載參考。

Section II.2. Calibration and detection limits

Recommendations

- i. For spectrometric instruments, it is recommended to use the energy-dependent counting efficiency rather than a calibration factor to determine thyroid activity from the measurement result. For non-spectrometric instruments the use of a calibration factor is preferred.
- ii. The background must be subtracted from both calibration phantom and subject measurement readings. For non-spectrometric instruments the subject background should be measured on another body part of the subject (e.g. the thigh, forearm or shoulder) to ensure that the contributions of other incorporated radionuclides are correctly subtracted.
- iii. Detectors should be calibrated with thyroid phantoms and the calibrations should be traceable. It is recommended to use age-specific bi-lobed thyroid phantoms with volumes as recommended by ICRP (Table II.2.1). The thickness of the overlying tissue of the phantom should if possible be selected according to the age of the subject. Examples are given in Tables II.2.2 and II.2.3.
- iv. Spectrometric instruments may be calibrated with either ^{131}I or ^{133}Ba sources. It is recommended to calibrate non-spectrometric instruments with ^{131}I sources. If this is not possible then a mock source, as described in Section II.2.1, should be used.
- v. Neck to detector distances must be the same for calibration measurements and subject measurements.
- vi. If the detector has been calibrated for different ages then it is recommended to perform measurements at 'close contact', with the detector positioned in front of the thyroid and as close as possible to the neck but without touching the skin. The thyroid is positioned below the Adam's apple and above the clavicles.
- vii. For young children, it is recommended to use detectors of smaller sizes so that measurements at 'close contact' are possible.
- viii. If the detector has only been calibrated for the adult then it is recommended:
 - to perform the measurement at close contact and use the correction factors given in Table II.2.4, or
 - to perform measurement at distances of at least 20 cm and apply the adult calibration, provided the detection limit of the measurement is adequate.
- ix. For spectrometric and non-spectrometric instruments, it is recommended to calculate detection limits as given in Section II.2.4. For both types of instrument, the background peaks or other interfering peaks must be taken into account.
- ix. The minimum assessable dose depends on the detection limit and the time of measurement. To determine whether the measurement procedure is adequate, the minimum assessable dose should be calculated using the data in Table II.2.5. This enables a quick evaluation of the minimum assessable dose in terms of the committed effective dose or the absorbed dose to the thyroid. However, this table is not applicable if stable iodine has been administered.

圖 20. 甲狀腺體外劑量評估偵檢器校正與選擇建議

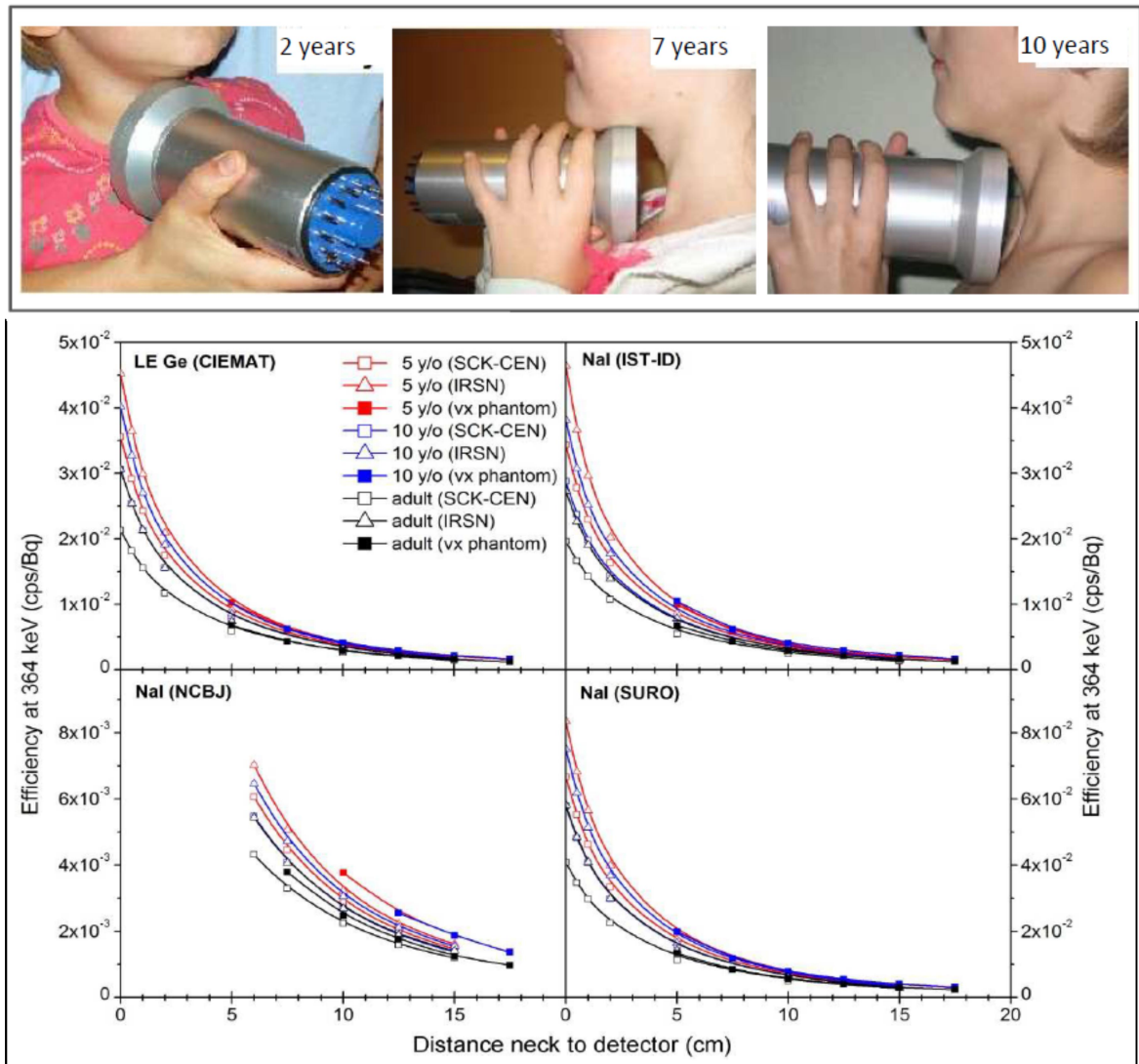


圖 21 .輻射偵檢器效率校正分析方法

Section II.6. Thyroid measurements made by members of public Recommendations	Section II.6. Thyroid measurements made by members of public Recommendations (continued)
The following recommendations are derived from [Lebacqz et al. 2017, Monteiro Gil et al. 2017]. i. How to identify a suitable instrument for measurement of dose rate over the thyroid Gamma dose-rate meters are preferred to count-rate meters for the reasons given below. Instruments dedicated solely to alpha-beta contamination measurement may cause errors in measurement data interpretation. A calibration factor for the conversion of the instrument readout to the ^{131}I activity in thyroid (e.g. $\mu\text{Sv}\cdot\text{h}^{-1}$ per kBq or cps per kBq) should be established unless dose/count rate results are only to be used for comparison with reference level values (generally expressed as ambient dose equivalent, $H^*(10)$) set by national authorities according to the IAEA concept of Operational Intervention Levels [IAEA 2017]. The calibration factor must be obtained with the support of professionals, who have the means to carry out calibration measurements with thyroid phantoms and metrological traceable sources. For dose-rate meters, the minimum measurable dose rate is $0.1 \mu\text{Sv}\cdot\text{h}^{-1}$. Preferred instrument dimensions: an effective area of the detector $\leq 15 \text{ cm}^2$ (or 5 cm in length for cylindrical instruments, typically small size Geiger-Muller tubes) is recommended. Instruments should have technical support from the manufacturer, be well-documented, and have a simple instruction manual. Compliance with IEC 60846-1:2009 is recommended. A reference point for the instrument or a proper instrument orientation should be marked on the instrument case. The instrument should allow the operator to make readings when positioned in contact with the neck. Instruments with digital output are preferred, as they are generally easier to read than those with analogue outputs. Instruments with few switches and adjustable parameters are preferable as they are easier to use and less likely to be set up incorrectly. Malfunction warning and low battery warning should be included among the instrument functions. Advanced functions of data storage and logging may be useful if an established network of measurement data exchange is available. ii. How to perform simple function checks Read the instruction manual for the instrument. Allow the instrument to stabilise after switching on. Check instrument functions and settings as described in the instruction manual. Check instrument response to different dose rate levels to see readout change. For example, carry out dose rate measurements inside and outside a building.	iii. How to make simple measurements Allow the instrument to stabilise after switching on, and then perform function checks. A reading should only be recorded after the instrument reading has stabilised. If the reading is increasing then the user should wait until it starts to decrease, that is, it is fluctuating around a median value. It is the median value that should be recorded. The converse is also true; if the reading is decreasing then the user should wait until it starts to increase. When measuring a person, ensure at least a 3 m separation between the measured person and potentially externally contaminated people, except in the case of young children or vulnerable adults where the parent, guardian or carer can be closer. Ensure external contamination is removed from the neck of the measured person (e.g. by wiping) and that the instrument is protected against contamination (e.g. by covering the detector's window with thin plastic film). This is particularly important when the measurement is carried out close to the neck. Make a background measurement at the same monitoring location as the expected dose rate measurement over the thyroid while keeping potentially contaminated people at least 3 m away. The background measurement can be determined by measuring the thyroid of an uncontaminated person. Alternatively, an uncontaminated part of the body (usually thigh, forearm or shoulder) can be used for background measurements especially in cases where the detector is close to the skin. If this is not possible then the ambient background can be measured by holding the instrument up and taking the reading. Make the dose rate/count-rate measurement at the same monitoring location. Record the dose rate/count-rate reading for the background measurement and that for thyroid measurement. Record the units of the measured quantity. Calculate the net dose rate/count-rate by subtracting the background measurement from the thyroid measurement. Write a short measurement report (see below). If possible, repeat the measurement within the next few days and record the result with the previous one. iv. How to avoid giving erroneous results Read and follow the instruction manual of the instrument and any measurement procedure that has been specified. Carry out the dose rate/count rate measurement, preferably on people who have removed any external contamination. Be sure the ambient (background) dose rate/count rate is subtracted before interpretation of the result.

圖 22. 民眾參與甲狀腺體外劑量量測專家建議內容

● 主題 5. 車諾比與福島核災後放射性碘監測與量測方法更新及未來研究方向

此項議題由法國核能管制單位(IRSIN) Olivier Masson 進行報告，放射性碘在核災輻射物質外釋的過程中，因容易與大氣中物質進行化學反應，除氣態碘存在外亦可能吸附於懸浮微粒而隨氣流飄散，所以在進行放射性碘吸入劑量評估時，氣態碘與懸浮微粒型態碘之比例，是核災後實際劑量評估之依據，但根據歐盟至今各國監測設施，大部分以抽氣濾紙過濾空氣中懸浮微粒碘，對於依賴活性碳吸附才可偵測之氣態碘設備僅佔 30%，這將對於吸入體內劑量過低評估(under-estimated)達差 8 倍，尤其對於鄰近核設施之民眾來說，氣態碘才是主要的劑量貢獻來源如圖 23。

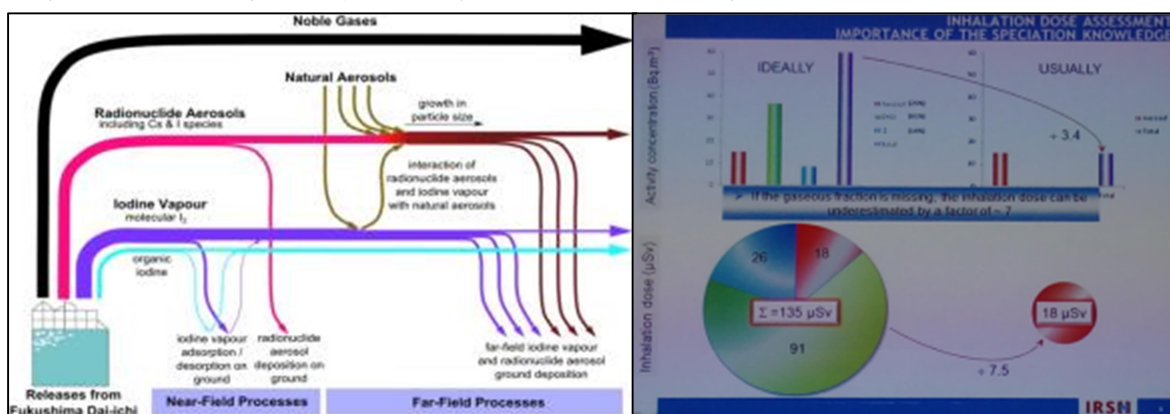


圖 23. 放射性碘擴散與現行碘體內劑量低估之情況

此外因放射性碘之半衰期僅 8.04 天具分析時效性，且引用 ICRP 報告其佔 90%體內劑量，更加說明未來對於放射性碘於災後鄰近且短期內之劑量，需重新建立評估與量測方法，總結時 Masson 博士坦言歐盟依循車諾比核災後之偵測經驗，所訂立放射性碘偵測方法為抽氣濾紙過濾空氣中懸浮微粒碘後定量分析，然而 IRSIN 已完成氣態與懸浮微粒碘偵測技術與設備模組化如圖 24，並規劃未來推廣至各地監測站。



圖 24. IRSIN 放射性碘進階量測流程與設備實體外觀

六、心得與建議

(一)、心得

1. 3 天主題會議由 ICRP 與歐盟研究平台共同合作發表研究成果，關於輻射防護各項研究最新發展，包括新假體模擬技術，進階更新以往報告中劑量轉換因子，相對影響後續劑量管制標準，如弱穿輻射對於眼球與皮膚之劑量限值未來將有所變動；關於低劑量與低劑量率輻射生物機率效應研究，會議中提出新研究成果(JANUS PROJECT)佐證，以往由長崎及廣島核爆調查，推定線性外堆(extrapolation)與 LNT 模式結果呈現過保守高估之現象，導致接續輻射致癌風險評估定量分析上之誤差，且強調機率效應在不同的癌症(血癌，骨癌或皮膚癌)或體內器官功能失效不同，未來建議各別評估；體內劑量評估部分，則提出新體內核種傳輸及器官模擬構型模式，由 ICRP134 號及後續 137 號中更新攝入核種約定有效劑量轉換因子，亦可供本會現行輻射防護法規中相關內容更新之參考。

2. 關於民眾參與環境輻射量測議題，這次參與獲知捷克核能管制及輻射防護官方單位已推行此方案，其計畫架構與預期成效宣傳海報如圖 25，而第三方非營利組織(NGO)以共享開放資料(open data)核心價值，突破擁核與廢核理念對抗，強調即時數據傳輸收集網路展示方法，忠實呈現科學數值，達到「讓數據說話」之目標，例如 SAFecast(網址：<https://blog.safecast.org>)，造訪該網站，自 2011 年成立起至 2016 年累積偵測數據達 4 千萬筆，數據累積速度急遽增加，以全球的尺度來看，參與量測民眾及偵測結果已遍及日本、冰島、歐洲及美國，部分涵蓋澳洲、南非及南美洲智利，最為特別的是台灣偵測結果亦在圖台上展現如圖 26，代表民間明顯已加入該平台，詳查其細部資料顯示偵測時間，經緯度、計數率、資料上傳人員及設備編號等，甚至編輯 JASON 開放資料模式供下載使用；檢視該平台所推廣名為 bGeigie nano 蓋格偵檢器，規格項目如圖 27，可經由網路訂購(550 美元)且經由網路影片教學自行組裝如圖 28，需特別注意的是關於驗證(Certification)部分，依規格說明尚待建立中。



New Approach to Radiation Monitoring: Citizen Based Radiation Measurement

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Introduction

Both the Fukushima Dai-ichi NPP accident in Japan in 2011 and the Chernobyl NPP accident in USSR in 1986 similarly to the first one have shown a necessity to find a way how to improve confidence of the public to official authorities. It is important especially in such a case of severe accidents with significant consequences on large inhabited areas around the damaged NPP. A lack of public confidence to officials was caused mostly by rather poor communication between official authorities and the public, as well by restricted access to the information for the public. It may have extremely negative impacts on the public understanding of actual situation and its possible risks and on public acceptance of necessary protective measures and on public participation in remediation of the affected areas.

One of possible ways to improve the situation can be implementation of citizen radiation monitoring on voluntary basis. Making sure that the official results are compatible with public self-measured ones, the public probably gain more confidence in them.

In the Czech Republic the implementation of such an approach is tested in the framework of security research founded by the Czech Ministry of the Interior - the research project RAMESIS solved by SURO. The paper shows selected results reached during the first two years of this project.

Radiation accident



SAFECAST bGeigie Nano



- price ~800 USD (Amazon) for a kit to assembly (soldering needed)
- LND 7517 pancake type GM detector
- OLED graphical display, built-in GPS
- realtime data logging to microSD card (5s intervals)
- Li-Ion battery for up to 40 hours operating time
- weatherproof polycarbonate outdoor case
- simple to use - "switch on, wait few minutes and go"



Crisis management

First responders

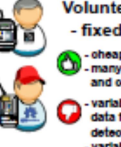


Professional field teams

- sensitive equipment, knowledge / training / experience
- use protective equipment, know how to avoid risk
- limited time (working hours legal restrictions)
- often not enough manpower for all the tasks



- citizen data can help the professionals to identify potential hotspots to measure preferentially
- citizen networks can give data quickly even for a large area because of quantity of detectors
- indicative data (cannot be the only basis for countermeasures !!!)



Volunteers (SAFECAST etc.)

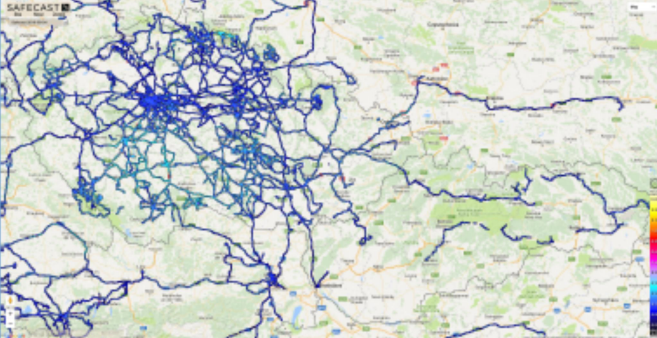
- fixed or mobile detectors
- cheap devices are easily accessible
- many people want to get involved and can alternate
- variable detector quality / sensitivity and data format especially for homemade detectors
- variable knowledge of the volunteers

Suitable detector for volunteers

- affordable price
- reasonably sensitive detector
- open hardware and software so it is easy to identify bugs and solve them
- no custom settings regarding measurement processing (eg. calculating dose rate from CPM etc., so the operator cannot produce wrong data due to incorrect settings)
- built-in GPS for field use, sufficient battery life

Our recommendation, especially for field use, is the Safecast bGeigie Nano detector.

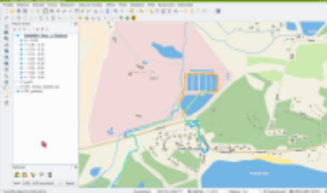
Measurements for area of the Czech Republic & Slovakia - Safecast web map



Offline maps, QGIS plugin, various utilities and information materials

Offline mapping solution

- free and open-source software QGIS
- QGIS is multi-platform, supports Windows, Linux and Mac
- online map background (OpenStreetMap, Bing, Google)
- offline maps - created by SURO, OpenStreetMap based
- bGeigie data directly to QGIS using plugin developed within SURO research project
- plugin offers predefined color scales
- user can remove data he does not want to provide to the authorities/Safecast
- SURO also developed simple conversion utility for displaying the bGeigie data in spreadsheet like MS Excel



Detectors tested by SURO

- 1) devices under 40 USD
 - FTLab SmartGeiger (35 USD) - tiny semiconductor detector for smartphones
 - RadioactivePhone (~35 USD) - with SBM-20 GM tube, not for mobile use
- 2) devices under 130 USD
 - Xeropen gelger counter
 - Chinese portable device with unknown GM tube, no GPS
 - MightyOhm Gelger Counter, MyGeiger
 - hobby kitz with SBM-20 GM tube, without outdoor case
 - possibly expandable with GPS etc.
- 3) devices 500-1000 USD
 - PoliMaster PM1912 RadFlash II (~900 USD)
 - usb "thumb drive", no display, proprietary SW

Safecast bGeigie Nano (~600 USD - Amazon)

- designed for simple and mobile radiation data logging, has GPS

GammaScout (~500 USD)

- hand-held detector - no GPS, not designed for continual mobile logging

Only Safecast bGeigie Nano has built in GPS and realtime data logging within price range under 1000 USD + open HW/SW documentation

Conclusion

Following the huge development of various crowdsourcing projects, volunteer/citizen-based monitoring networks and current positive experience with SAFECAST community in Japan it is really important not to ignore this.

Both sides can benefit from collaboration - official authorities can get supporting data to better identify hotspots where to send professional field teams preferentially to save time while the volunteers change the role from passive victims / witnesses to active participants. The volunteer can also get professional support regarding data interpretation and advices in order to improve their equipment and data quality. Long term collaboration between official authorities and volunteer communities can significantly improve public confidence in official authorities.

References:

Safecast
www.safecast.org

Safecast on Wikipedia
www.wikipedia.org/wiki/Safecast_(organization)

Safecast bGeigie Nano - QGIS plugin and other software
www.bf.ly/safecastqgiseng

Detektor záření SAFECAST a jeho využití pro veřejnost
www.suro.cz/izvryzkum/vyvedly/safecast

圖 25. 捷克輻射防護管制單位推行民眾量測之成果海報

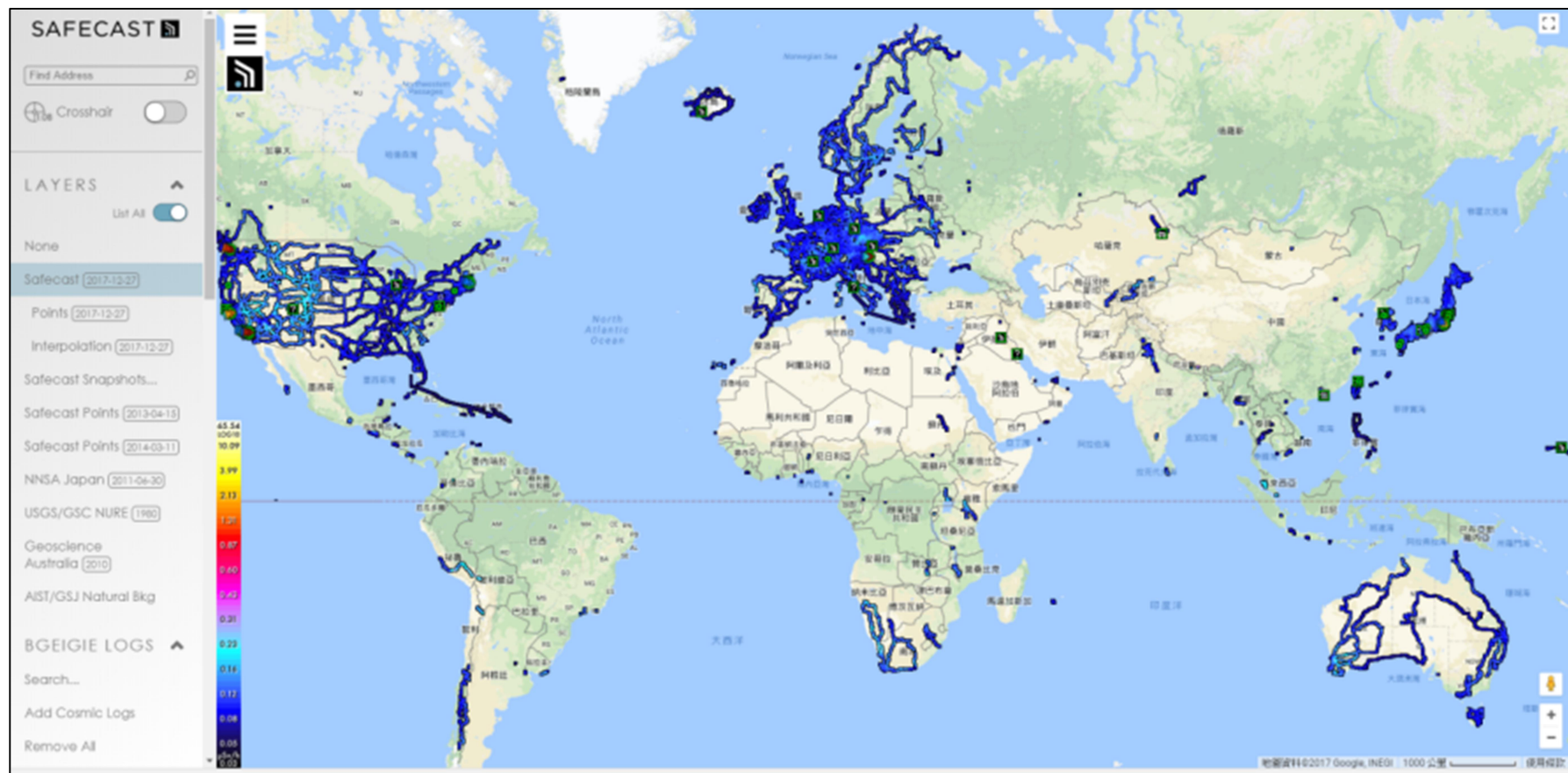


圖 26. SAFECAST 輻射偵測數據共享平台全球執行成果

Features

Modes

The bGeigie Nano has three modes.

bGeigie Mode	xGeigie Mode	iGeigie Mode
Mobile radiation sensor logging with display indicators for CPM and $\mu\text{Sv/h}$, number of satellites locked, altitude (m), distance traversed (km), total duration of measurement (h:m), and time stamp (dd:hh:mm:ss)	Geiger counter (no logging) with display indicators for $\mu\text{Sv/h}$ dose-rate (Cs137), max dose-rate, dosimeter, CPM, Bq/m ² (Cs137), time stamp, and alarm LED	iPhone-compatible output for the Safecast iOS app that displays dose rate, maps data, and uploads data to the Safecast API in real time

- Note that there is a **hot switch** for switching between bGeigie (logging) and xGeigie (no logging) modes. Data recording will be paused in xGeigie mode.

Other Features

Feature	Description
Dual use modular design	main unit can be taken out of case for α -, β -detection, for careful use as surface contamination spot meter
Operating range	$\mu\text{Sv/h}$: .000 to 1,000 ; mR/hr: .000 to 100 ; CPM: 0 to 350,000
Accuracy	+/- 10% typical, +/- 15% maximum [* as with Onyx ?]
Temperature range	-20 to +50 C, -4 to +122 F [* as with Onyx ?]
Calibration	Cesium-137 (gamma from daughter metastable Barium)
Gamma sensitivity	334 CPM per $\mu\text{Sv/h}$ (3340 CPM per mR/hr) referenced to Cs-137
Certifications	(in progress, TBA*)

圖 27. SAFECAST 推廣 bGeigie nano 蓋格偵檢器規格項目



圖 28. bGeigie nano 蓋格偵檢器手動組裝及設備外觀

3. 在福島核災後經驗回饋部分，許多對應修訂方案陸續提出，包括以往以預估輻射擴散模式評估可減免劑量之方法，改以現場量測數值與機組狀況作為應變行動基準；對於災後復原禁入區解禁向民眾說明，必須釐清民眾關切議題(致癌風險)並避免提出專業名詞困擾民眾返鄉意願；另外關於應變區內老人，安養院病人等相對缺乏交通工具等族群須特別注意安排，且對於多種情境下疏散路線可能之變化需事先規劃等。日本核災後的改善作法，我國亦已同步進行修正。

4. 有關放射性碘的量測方法，未來技術將朝向氣態碘之偵測，於本次會議中，法國核能管制單位說明已完成相關技術開發與設備建置，設備部分結合高低流量抽氣機，啟動順序則設定低流量抽氣機抽氣樣品若偵測核種活度增加時，則啟動高流量抽氣機額外流經活性碳界以捕捉氣態碘，並強調該設備能定時加熱活性碳床，克服水氣影響活性碳床捕捉碘效益，該項發明具專利，因此是否有技轉給設備廠商模組商業化，仍待繼續查詢相關資料。

(二)、 建議

1. 核設施監測項目中關於外釋碘的監測，除現行採即時空間劑量率變化趨勢之監測方法外，建議可參考法國 IRSN 所設計之空浮監測設備與技術，研究加強氣態碘偵測分析能力之可行性。
2. 關於核災後攝入碘體內劑量之評估，除由 ICRP 建議之攝入活度推導約定有效劑量方法外，建議可持續瞭解法國 IRSN 提出之「CAtHyMARA 計畫」，世界各國作法及其技術指引，更新或建立使用輻射偵檢器進行甲狀腺體外直接量測之技術。

附件二

第 4 屆國際輻射防護委員會(ICRP)會議議程

ICRP October 10-12 2017 Paris, France ERPW Preliminary programme		Tuesday 10 october		Wednesday 11 october		Thursday 12 october				
9:00	WELCOME BREAK		ICRP & MELODI Session Effects, Risks, and Detriment at Low Dose and Low Dose-Rate		ERPW Session 3 Why is radioecology an essential science when analyzing human population exposure?		ERPW Session 4 Benefit vs risk in diagnostic and interventional radiology, nuclear medicine, and radiotherapy			
9:30							ICRP & NERIS Session Post-Accident Recovery		ERPW Session 13 Eye lens exposure and monitoring	
10:00			OPENING CEREMONY							
10:30										
11:00			BREAK				BREAK			
11:30			ICRP & MELODI Session Effects, Risks, and Detriment at Low Dose and Low Dose-Rate		ERPW Session 5 Medical radiation incidents/accidents		ERPW Session 6 Internal dosimetry			
12:00							ICRP & NERIS Session Post-Accident Recovery		ERPW Session 14 Individualized approaches for radiation protection	
12:30										
13:00										
13:30	LUNCH				LUNCH					
14:00			ICRP & EURADOS Session Advances in Dose Coefficients		ERPW Session 1 Ethics in radiation protection		ICRP & ALLIANCE Session Integrated Protection of People and the Environment		MELODI award ceremony	
14:30										
15:00										
15:30										
16:00			BREAK							
16:30	ICRP & EURADOS Session Advances in Dose Coefficients		ERPW Session 2 Management of emergency and post- accident situations: how to optimise population evacuation zones and related decision making processes?		ICRP & EURAMED Session Advanced Radiotherapy: Benefits and Radiation Protection due to Developments in Imaging, New Technologies, and Stratification		ERPW Session 9 Use of observatory sites for integrated long-term research activities		ERPW Session 10 Harmonization of practices enabling patient dose repositories	
17:00							ERPW Session 11 Radioactive Iodine: gaps and knowledge needed for nuclear crisis integrated management		ERPW Session 12 Dosimetry in complex fields	
17:30									ICRP & ERPW SUMMARY AND CONCLUDING REMARKS	
18:00	RECEPTION									
19:30										
20:00										

參與第 4 屆國際輻射防護委員會(ICRP)會議證明



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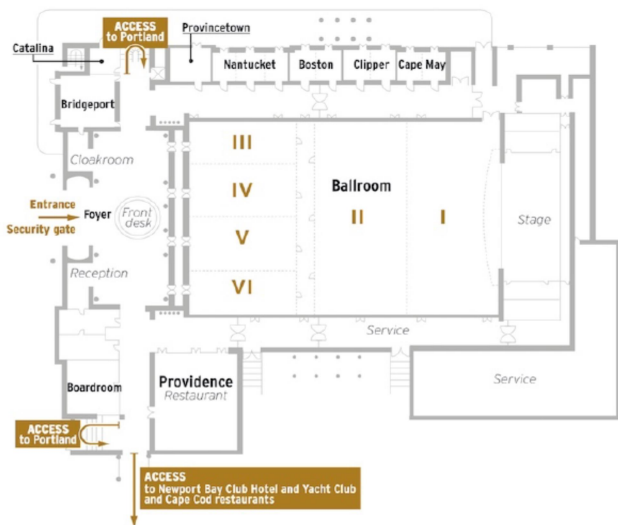







<http://icrp-erpw2017.com>

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