香港環境輻射監測技術報告第 41 號

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Environmental Radiation Monitoring in Hong Kong

香港環境輻射監測摘要
Summary of Environmental Radiation Monitoring in Hong Kong

2020

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香港天文台

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摘要

香港天文台環境輻射監測計劃在二零二零年踏入第三十四年。年報收錄了監測計劃在二零二零年的主要工作內容、測量方法及結果。年報亦介紹了新的工作項目和轉變。

在二零二零年，輻射監測網絡除了於十月五日早上短暫時間在京士柏測量到由於本地自然天氣變化引致相對較高的輻射水平外，其餘時間錄得的環境輻射水平俱在正常本底變化範圍之內。天文台在不同的環境及食物樣本中測量到微量的人工放射性核素，包括銫-137、氚、鍶-90 及鈈-239。它們的活度水平與多年來的結果並沒有顯著分別，相信這些放射性核素主要來自一九四五至一九八零年間的大氣核武試驗。

在發展項目方面，天文台在二零二零年將更新後的平洲自動伽馬譜法系統投入業務運作，並完成在全部輻射監測站安裝新型號的高壓電離室，陸續開始試行運作。此外，天文台亦於二零二零年更新了京士柏實驗室伽馬譜法系統的部分探測器及硬件，並開展了更新液體閃爍計數系統的工作。

二零二零年的測量結果顯示，與大亞灣核電站及嶺澳核電站運作之前相比，香港的環境輻射水平、環境樣本及市民日常食用的食品中的人工放射性核素活度並沒有顯著變化。

ABSTRACT

The Environmental Radiation Monitoring Programme of the Hong Kong Observatory entered its thirty-fourth year in 2020. This annual report incorporates salient features of the work of the programme during 2020, including a brief report on measurement methods and results, highlights of relevant new work and changes.

In 2020, apart from the relatively high radiation levels recorded at King's Park for a short period of time due to natural changes in local weather on the morning of 5 October, the ambient radiation levels recorded by the radiation monitoring network during the rest of the year were all within the normal background range. Traces of artificial radionuclides, including caesium-137, tritium, strontium-90 and plutonium-239, were detected in various environmental and food samples. The activity levels of all these radionuclides were not significantly different from those recorded in past years. Their presences were primarily attributed to the atmospheric nuclear weapon tests between 1945 and 1980.

Regarding new developments, the replacement Automatic Gamma Spectrometry System (AGSS) in Ping Chau was put into operation in 2020. Meanwhile, installation of new model High Pressure Ionization Chambers (HPICs) in all radiation monitoring stations was completed and they started trial operation progressively. Besides, the Observatory also replaced part of the detectors and hardware of the gamma spectrometry system in the King's Park Radiation Laboratory and commenced the replacement work of the liquid scintillation counting system in 2020.

Based on the measurement results in 2020, it is concluded that there was no significant change in the ambient radiation levels in Hong Kong as well as the activities of artificial radionuclides in the environmental samples and foodstuffs consumed by Hong Kong people, as compared with those before the operations of the Daya Bay and Lingao nuclear power stations.

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1. 引言

香港天文台早於一九六一年開始監測香港的環境輻射水平，並參與由國際原子能機構(IAEA)和世界氣象組織(WMO)舉辦的國際性環境輻射監測計劃。

因應興建廣東大亞灣核電站，天文台於一九八三年開展了一項全面的計劃，以監測核電站運作前後香港的環境輻射水平。該計劃名為「環境輻射監測計劃」(ERMP)，分兩個階段進行。ERMP 第一個階段為期五年，稱為「本底輻射監測計劃」(BRMP)，於一九八七年至一九九一年進行，務求在一九九四年大亞灣核電站投產之前，確定香港的本底輻射水平，作為基準線，以判別核電站運作後可能為香港輻射水平帶來的影響。監測結果可參考 BRMP 的報告（*香港天文台，1992*）。

ERMP 的第二階段由一九九二年開始運作至今，內容涵蓋 BRMP 內的所有重要項目，並因應累積的經驗及最新科技發展來修訂採樣及測量工作。ERMP 是一項持續進行的計劃，目標是監測香港環境輻射水平的長期變化，尤其是大亞灣核電站與嶺澳核電站分別在一九九四年及二零零二年投入運作後可能出現的任何變化。圖 1 所示為目前廣東省各核電站的位置分佈圖。

ERMP 的監測結果在計劃的年報和摘要中發表(https://www.weather.gov.hk/tc/publica/pubrm.htm)。讀者可參閱有關報告，以瞭解計劃的採樣、測量及品質保證工作的詳情。自二零零三年開始，監測計劃的年報實行精簡化，年報只收錄計劃的重點，包括測量方法和結果的總結，及該年工作的摘要、轉變或新措施。

本報告的第 2 章介紹監測計劃的取樣工作、環境輻射水平、食物和環境樣本活度的測量方法及儀器，以及品質保證。第 3 章則臚列二零二零年的測量結果及所得的結論。

2. 取樣、測量及品質保證

ERMP 的焦點集中在大氣、地面和水體三個主要照射途徑。測量工作主要包括兩個部份。第一部份是直接測量香港的環境輻射水平，第二部份是測量香港的環境樣本及市民日常食物中的人工放射性物質。圖 2 顯示二零二零年實時測量環境輻射的地點，圖 3 所示為二零二零年其他環境伽馬輻射的測量地點及環境樣本的收集點。表 1 列載二零二零年的取樣及分析概要。

2.1 環境輻射水平的直接測量

2.1.1 輻射監測網絡

天文台的輻射監測網絡包含分佈全港不同地點的十二個監測站(圖 2)，全面地測量香港境內的環境伽馬輻射水平。

每個輻射監測站均裝設一個高壓電離室(Reuter-Stokes Model RSS-131/RSS-131-ER environmental radiation monitor)，不斷測量環境伽馬輻射劑量率，並透過政府專用通訊網絡及其他數據傳輸渠道，每一分鐘將數據傳送至天文台總部。天文台於二零二零年在全部十二個監測站完成安裝新型號的高壓電離室(Reuter-Stokes Model RS-S131-200 environmental radiation monitor)，並逐一開始試行運作。待運作暢順後，預計新型號的高壓電離室會分階段投入業務運作，取代舊型號的高壓電離室。

天文台在互聯網上發放各監測站錄得的每小時平均環境伽馬輻射劑量率數據，供市民參考，網址為：

https://www.weather.gov.hk/tc/radiation/monitoring/index.html

在八個指定輻射監測站裝設的在線伽馬譜法分析網絡在二零一八年全面投入業務運作(圖 2)。伽馬譜法分析儀型號

為 RS250 Gamma Monitoring System，由 Radiation Solutions Inc. 公司製造，採用碘化鈉(NaI)探測器，實時監測環境中之伽馬放射性核素及輻射水平。伽馬譜法分析儀數據每一分鐘傳送至天文台總部。這些數據能幫助及早判別環境中有沒有異常的人工伽馬放射性核素，進一步提升應急響應及事故評估的能力。

2.1.2 熱釋光劑量計網絡

香港天文台於一九八零年代末開始使用熱釋光劑量計，測量長時間累積的環境伽馬輻射劑量。在二零二零年，熱釋光劑量計網絡包括二十九個位於香港不同地點的固定監測站（圖 3）。這個網絡使用 Harshaw 8807 型號的氟化鋰(LiF:Mg,Ti)及氟化鈣(CaF_2:Dy)熱釋光劑量計。為確保數據的統計精確度，每個監測站均設有五個一組的劑量計。熱釋光劑量計每季更換及讀取數據一次。

2.1.3 空中輻射監測系統

香港天文台在一九九八年開始進行空中輻射監測，並於二零一三年更換了監測系統。目前運作之系統由Pico Envirotec Inc. 公司製造，設有四個約2.5公升碘化鈉(NaI)探測器，可安裝在政府飛行服務隊的直升機上，以進行測量，錄得的計數率數據有助檢測環境輻射水平。

空中輻射監測系統能以輻射煙羽追蹤模式來測定香港上空有否出現輻射煙羽及鑑定其影響範圍。當輻射煙羽經過本港後，該系統可以轉為地面輻射污染測量模式運作，判別受輻射沉降物污染的地區。進行監測時，該系統可在直升機上即時顯示探測位置、伽馬圖譜、譜法分析結果及伽馬劑量率等資料。

在二零二零年，政府飛行服務隊開始運作新型號 Airbus H175 獵豹直升機。為配合新型號直升機的配置，空中輻射監

測系統在安裝方面亦需作出改動。系統探測器由原先安裝在直升機機艙內，改為在直升機外部的黑色吊艙內。這改動讓探測器更接近周圍環境，提高了環境輻射水平的探測效率。此外，由於新型號直升機配備衛星傳輸系統，輻射測量數據可實時傳送至天文台總部。

空中輻射監測系統的優點是它可以在偏遠、陸上交通難以到達的地點進行輻射巡測。每年天文台均會利用空中輻射監測系統作常規測量，收集環境輻射水平資料及監測輻射水平隨高度的變化。

2.1.4 自動伽馬譜法系統

自一九九六年起，香港天文台在大鵬灣平洲上設置了一套自動伽馬譜法系統(圖 2)，以便及早測量核電站可能排放的人工放射性核素。該系統由一個鍍上硫化鋅(ZnS)的塑膠閃爍器、一個高純度鍺(HPGe)探測器和一個碘化鈉探測器組成。系統分別利用一個迴轉空氣濾紙鼓和一個碳濾盒不斷地收集大氣飄塵及氣態碘，空氣濾紙鼓和碳濾盒的流量分別為約每小時 30 立方米及 4 立方米。碳濾盒每週自動更換一次。大氣飄塵中的阿爾法及貝他活度利用硫化鋅閃爍器測量，然後計算出來；大氣飄塵釋出的伽馬射線利用鍺探測器測量及伽馬譜法軟件作自動分析；碘-131 活度則利用碘化鈉探測器以量度碳濾盒。

系統會每五至十五分鐘將阿爾法和貝他的活度、碘-131 的活度及伽馬譜法分析結果等數據傳送至天文台總部。

天文台於二零一八年開展更新上述系統的工作。新系統完成測試及優化後，在二零二零年九月投入業務運作。它的運作模式跟舊系統大致相若，而在硬件及軟件設計方面有改良，主要包括：

(a) 採用更可靠的離子注入型硅探測器以代替鍍上硫化鋅的塑膠閃爍器測量大氣飄塵中的阿爾法及貝他活度；

(b) 採用卡帶式空氣濾紙設計以代替迴轉空氣濾紙鼓收集大氣飄塵，減少硬件數目並提高伽馬測量的時間分辨率，空氣濾紙流量改為每小時 15 立方米；及

(c) 將所有測量數據的更新頻率統一為十分鐘一次，方便分析之用。

2.1.5 流動輻射監測站

在陸上流動輻射監測方面，天文台目前擁有兩部輻射巡測車，每部巡測車均設有流動輻射監測站，配備多款便攜式及經特別設計的儀器，用作收集樣本、或作常規和應急輻射測量。

巡測車的主要儀器見下表:

儀器	**位置**	**用途**
碘化鈉伽馬能譜探測器 (Alpha Spectra, Inc. 16D16X64SS/3.5)	安裝於車內	探測環境中的人工伽馬放射性核素。
高容量空氣取樣器 (Hi-Q Environmental Products) （流量約 54 m^3h^{-1}）		通過車頂的氣管入口抽取外間的空氣樣本。
放射性碘取樣器 (Hi-Q Environmental Products) （流量約 4.8 m^3h^{-1}）		
伽馬劑量率探測器 (Seibersdorf SSM1-07)	安裝於車頂	探測器可連接至車內的便攜式巡測儀，讓車內的工作人員可以連續不斷地讀取站外的伽馬劑量率。
便攜式高壓電離室 (Reuter-Stokes RSS-131 / RSS-131-ER)	安裝於車內，在有需要時可移至車外的測量地點使用	安裝於車內時可測量巡測路線上的環境伽馬輻射水平。在測量地點時，工作人員亦可把高壓電離室的感應器安置在車外離地面一米高進行測量。
便攜式巡測儀 (Seibersdorf SSM-1)	置於車內，有需要時運送至測量地點使用	配備蓋革彌勒管，可以測量環境伽馬輻射劑量率。
表面污染掃描儀 (Berthold Technologies LB-124)		配備硫化鋅閃爍器，工作人員利用掃描儀在離表面一厘米的位置量度阿爾法、貝他及伽馬表面污染。

儀器	位置	用途
便攜式伽馬譜法儀（Canberra ISOCS 原位置刻度系統/高純度鍺探測器）	置於車內，有需要時運送至測量地點使用	在測量地點對環境放射性核素作伽馬譜法分析。

此外，兩部巡測車的車頂均裝置了氣象儀器收集風向風速、氣溫及濕度等天氣數據，亦配置了攝影機監察環境。

流動輻射監測站日常用於常規巡測、收集樣本及應急演練，並定期到本港指定地點收取環境輻射數據。

2.1.6 高空輻射探測

天文台利用氣球攜帶 Meisei RS-06G 型號探空儀及附帶的輻射探測組件在京士柏進行高空輻射探測工作。每個輻射探測組件（Meisei MNS-13 型號）含有兩支蓋革彌勒(Geiger Müller)管，一支是只量度伽馬輻射的伽馬管，另一支是量度伽馬及高於 0.25 兆電子伏(MeV)貝他輻射的伽馬及貝他管。伽馬管的輻射探測效率較伽馬及貝他管高。輻射探空儀傳回地面的數據經地面站的高空探測系統接收和處理。

天文台每年定期在不同的天氣情況下進行高空輻射探測，以收集輻射水平隨高度變化的數據。

2.2 食物及環境樣本取樣安排

2.2.1 大氣樣本

ERMP 所收集的大氣樣本包括大氣飄塵、濕沉積物(降雨)、總沉積物(濕沉積物加上乾沉積物)、氣態碘及水蒸氣。各取樣器及取樣方法見下表:

大氣樣本	取樣器	流量	取樣方法
大氣飄塵	高容量空氣取樣器 (Hi-Q Environmental Products 4200 AFC-BRL-KIT/230、BRL-3000M 及 HVP 4300 AFC)	一般設置為 17 m^3h^{-1}	透過高容量空氣取樣器內的濾紙每週收集常規大氣飄塵樣本。
	更高容量空氣採樣器 (F&J Specialty Products UHV-600)	一般設置為 800 m^3h^{-1}	透過更高容量空氣採樣器內的濾紙在有需要時收集大氣飄塵樣本。
濕沉積物	頂部設有漏斗的容器之濕沉積物取樣器	-	每個收集點都會放置一個漏斗容器以收集雨水作測量,旱季時會增至三個以增加收集的雨水量。
總沉積物	直徑 260 毫米,盛有蒸餾水的不銹鋼圓盆之總沉積物取樣器	-	樣本每週收集一次。
氣態碘	裝有浸滲銀沸石濾盒之 Hi-Q Environmental Products CMP-0523CV/230 放射性碘取樣器	一般設置為 2.5 m^3h^{-1}	濾盒每週收集和更換一次。
	附設於 F&J Specialty Products UHV-600 更高容量空氣採樣器的浸滲 TEDA (三乙烯二胺)碳濾盒	一般設置為 7.0 m^3h^{-1}	在有需要時以濾盒收集氣態碘樣本。
水蒸氣	裝有煅石膏濾盒之 Pylon Electronics Inc. VFP-20 氣態流出物取樣器	一般設置為 0.12 m^3h^{-1}	每月隨機選擇一個星期間歇地收集樣本,直至取樣總時數達三十六小時為止。

天文台每週定期在京士柏、沙頭角和元五墳(圖 3)收集一次大氣飄塵和濕沉積物樣本。此外，在其他九個輻射監測站亦裝置有這些儀器，以便在應急時收集大氣樣本。天文台亦在京士柏收集總沉積物、氣態碘及水蒸氣樣本。在應急及演練時，亦可利用更高容量空氣採樣器增加大氣飄塵樣本的容量，有助提高測量效率。

2.2.2 食物樣本

香港天文台從主要食物分銷點、批發市場和供應商收集各類市民日常食用的陸生和水生食物樣本，並特別著眼於本港和深圳出產的食物。

2.2.3 飲用水、地下水及海水

經處理的飲用水樣本，是從九龍和屯門配水管，以及沙田、屯門和油柑頭濾水廠(圖3)收集的。未經處理的飲用水(原水)，則從萬宜水庫、船灣淡水湖、木湖 B 抽水站，以及沙田、屯門和油柑頭濾水廠(圖 3)收集。水務署的工作人員每三個月抽取前述兩種飲用水樣本一次，交香港天文台作輻射測量。

在房屋署職員、屋邨管理員及寺院人員等協助下，天文台在 2020 年於以下五個地點(圖 3)抽取地下水樣本[#]：長康邨(青衣)、環翠邨(港島東)、華富邨(薄扶林)、富山邨(東九龍)及清涼法苑(屯門)。

在環境保護署協助下，天文台每季均會交替在四個常規取樣地點之其中兩個抽取海水樣本。四個常規取樣地點(圖3)位於香港東部沿岸，分別為橫瀾島、火石洲、大浪灣及赤洲附近的海域。海水會從三個不同深度抽取：上層(水面下2.5米)、中層(與水面及海床等距)和低層(海床上2.5米)。海水中的懸浮粒子樣本是經由薄膜過濾海水樣本後收集。

由於位於元朗的地下水抽水系統停止運作，自二零一九年起地下水取樣地點由六個減至五個。礙於土地用途及環境改變，合適的地下水取樣地點變得難以找尋，天文台會定時檢視香港的取樣地點狀況。

2.2.4 土壤及沉澱物樣本

天文台在香港境內三十九個指定地點抽取土壤樣本，每一地點取樣周期為五年。每個地點抽取的土壤樣本均來自兩個不同的深度：上層由地面至 15 厘米深，下層則由 15 至 30 厘米深。二零二零年的取樣地點為京士柏、沙田、西貢、清水灣、萬宜水庫西、萬宜水庫東、北潭凹及白沙澳(圖 3)。

潮間帶土樣本每季在白沙灣、尖鼻咀和沙頭角三處沿岸地區(圖 3)收集。樣本從兩個不同深度層抽取，上層從表面至 15 厘米深，下層則自 15 至 30 厘米深。另外，土木工程拓展署每年在大灘海、龍蝦灣、索罟灣和西區碇泊處四個地點(圖 3)協助收取海床沉澱物樣本。

表 1 列載二零二零年樣本取樣及分析概要。

2.3 食物及環境樣本的實驗室測量

食物及環境樣本經處理後，其放射性分析均於京士柏的輻射實驗室進行。

表 1 列出監測的主要人工放射性核素。

每個樣本按照不同樣本類別及測量目的，經過下列一項或多項程序分析：

(a) 伽馬譜法分析

伽馬放射性核素的活度是採用伽馬譜法系統測量。該系統設有六個高純度鍺(HPGe)探測器。天文台於二零二零年更新了其中兩個探測器及相關數位訊號分析器，預計餘下的探測器及硬件會在二零二一年完成更新。目前六個探測器中有五個由 Ortec 公司製造，另外一個由 Mirion (前稱 Canberra)公司製造。系統其中四個探測器使用液態氮冷卻，另外兩個(Ortec 公司製造)由電機冷卻，互相補足。

(b) 液體閃爍計數法

氚[†]的活度是採用 Perkin Elmer 公司製造的 TriCarb 3170 TR/SL 型號之液體閃爍計數系統測量。更新該系統的工作於二零二零年開展，預計新系統於二零二一年投入業務運作。

(c) 低本底總貝他計數法

鍶-90 的活度是採用低本底阿爾法-貝他粒子計數系統測量。目前使用的系統型號為 Berthold LB790，而用作備用的系統型號則為 Berthold LB770-2。

(d) 阿爾法譜法分析

鈈-239 的活度是採用阿爾法譜法系統測量。目前使用的系統型號為 Ortec Alpha Ensemble，而用作備用的系統型號則為 EG&G Ortec OCTETE PC。

有關各種量度參數的概要，例如樣本大小、計數時間及探測下限等，載列於表 2。

[†]氚主要是在宇宙射線進入大氣層時自然地形成，或在一九四五至一九八零年間大氣核武試驗中產生，而少量亦可能來自核電站運作(*UNSCEAR 2008*)。

2.4 本底輻射監測計劃(BRMP)及環境輻射監測計劃(ERMP)的測量值比較

在 2.1 至 2.3 節所敘述的輻射測量中，部份環境伽馬輻射監測站、自動伽馬譜法系統及部份環境及食物樣本的輻射測量在 BRMP 進行的五年間尚未開始運作，所以本報告中有關這些系統或樣本的輻射測量結果並沒有相應的 BRMP 範圍作為本底輻射比對。

雖然如此，自一九九二年 ERMP 第二階段開始運作多年來，所有 BRMP 已包含的輻射測量項目的長期測量數值均顯示香港的環境輻射水平及樣本中的人工放射性核素活度均沒有因核電廠的運作而產生實質的變化(*江如秋及李淑明，2017*)。在這個基礎上，本報告中凡沒有 BRMP 範圍的測量項目(即在 ERMP 第二階段運作後才開始測量的項目)均以該項目首五年測量值的變化範圍作為參考。此參考值的測量時段與 BRMP 最接近，因此在沒有其他可見的變數影響下，也可以被視為該測量項目的近似本底數值範圍。

2.5 品質保證

自一九八九年開始，天文台已參與國際及國家機構舉辦的測量比對及能力測試(*許建忠等，2007*)，當中包括國際原子能機構(IAEA)、英國國家物理實驗室(NPL)、世界衛生組織(WHO)及中國輻射防護研究院(CIRP)。近年，天文台亦參加了中國原子能科學研究院(CIAE)、上海市輻射環境監督站(ShRESS)及政府化驗所(GL)組織的比對。

在二零二零年七月，天文台參加了由 IAEA 安排就水樣本進行之放射性核素活度測量的實驗室能力測試。同年十一月，天文台亦參加了政府化驗所安排就檢定奶粉樣本中銫-134 及銫-137 活度之實驗室比對。詳情見 3.1.8 段。

除了參加測量比對及能力測試外，天文台亦透過內部品質保證程序，確保香港環境輻射監測結果的可靠性。

為了提升輻射測量工作的管理效能及品質，京士柏輻射實驗室提供的輻射測量服務及天文台的環境伽馬輻射水平測量服務的管理程序均是依據國際標準化組織所訂下的 ISO 9001 標準來運作，該兩項服務分別於二零零九年初及二零一五年底成功獲得 ISO 9001:2008 認證。隨著 ISO 9001:2015 版本的發布，天文台進一步改善了兩項服務的管理程序，輻射實驗室測量服務及環境伽馬輻射水平測量服務分別於二零一七及一八年成功通過新版本的認證審查。

認證機構會定期對上述輻射測量服務作跟進審查，核實其服務可繼續獲得 ISO 9001:2015 認證。輻射實驗室及環境伽馬輻射水平測量服務於二零二零年順利通過年度審查，標誌著所提供的優質輻射測量服務再一次得到認可。

3. 測量結果及結論

3.1 測量結果

3.1.1 輻射監測網絡

輻射監測網絡於二零二零年所錄得的年平均環境伽馬劑量率及一分鐘平均數據的變幅均載於表3a。

自輻射監測網絡運作以來，各監測站錄得的輻射水平一般會隨著季節轉變而出現數個百分點的變化。在下雨或當熱帶氣旋影響香港的情況下，變化會明顯較大，甚至高於平時水平的一至兩倍。

二零二零年環境伽馬劑量率的最大變幅是於十月五日錄得。當日早上香港受到與一道冷鋒相關的雷雨影響，在平洲

及京士柏錄得的一分鐘平均劑量率較該站的年平均值皆高出約1倍。而京士柏錄得的一分鐘平均劑量率為每小時0.281微戈，亦稍為高出本底輻射範圍(參考範圍見表3a)。

在線伽馬譜法分析網絡與輻射監測網絡相輔相成，當輻射監測網絡錄得較大變幅的輻射水平時，伽馬譜法分析網絡提供的數據可協助判別該變化是否由人工伽馬放射性核素引致。在二零二零年十月五日，位於平洲及京士柏的伽馬譜法儀錄得的環境劑量當量率數據亦出現明顯變幅，但譜法分析並沒有測得人工伽馬放射性核素，所以該站當日錄得的較高輻射水平是由於雨水將高空的天然伽馬放射性核素沖至地面而引致的。

除上述個案外，輻射監測網絡在二零二零年錄得的環境輻射水平均在本底輻射範圍之內。

3.1.2 熱釋光劑量計網絡

二零二零年各熱釋光劑量計站錄得的伽馬輻射劑量率的年平均值、標準差及變幅載於表 3b。所有監測站錄得的劑量率均在 BRMP 範圍之內。

3.1.3 空中輻射監測系統

在二零二零年四月、六月、九月和十一月，空中輻射監測系統以地面輻射污染測量模式分別於平洲、塔門、索罟群島和吉澳進行本底輻射測量，測量高度按地勢而改變，並保持着距離地面約一百米。測量過程中並沒有探測到人工放射性核素，圖 4 為測量當時這些地區的環境輻射計數率數據。

天文台亦於二零二零年二月在大鵬灣地區及西貢以輻射煙羽追蹤模式量度垂直輻射水平。直升機由海拔約一百米升至約一千米，測量輻射水平隨高度變化，過程中並沒有探測

到人工放射性核素。圖 5 顯示在大鵬灣和西貢地區所錄得的垂直輻射水平分佈數據。

一如以往觀測所得，在大鵬灣水面上所量度到的計數率在垂直方向並沒有明顯變化，基本上為本底輻射水平。

在西貢所錄得的垂直輻射水平分佈數據，亦一如以往觀測所得，在陸地上近地面所量度到的計數率明顯比海面上的水平高，主要是由於岩石及土壤比海水含有較多放射性物質所致。計數率數值自地面隨高度迅速遞減，直至達到相當於海面上所量度到的水平。

3.1.4 自動伽馬譜法系統

二零二零年平洲自動伽馬譜法系統錄得的數據載於表 4。全年並沒有探測到人工放射性核素，而所有測量結果均在環境輻射範圍內。

3.1.5 流動輻射監測站

二零二零年天文台在船灣淡水湖共進行了四次宇宙輻射測量，平均伽馬劑量率為每小時 0.032 至 0.035 微戈（見表 5），與往年所得的數據相近。

天文台自二零一七年開始以兩部搭載便携式高壓電離室的輻射巡測車每年於本港一些主要幹道上作常規的輻射巡測（巡測路線可參考圖 6）。在二零二零年，兩部巡測車合共進行了 160 次巡測。綜合整年錄得的數據，環境伽馬劑量率為每小時 0.060 至 0.223 微戈，與以往於相同的巡測路線上錄得的數據相近。

環境伽馬輻射水平之差異，一般由測量點附近的建築物、岩石和土壤等，以及當時天氣狀況所引致。圖 6 顯示了二零二零年巡測路線上錄得的伽馬劑量率、輻射監測網絡和

熱釋光劑量計網絡錄得的全年平均數據。

3.1.6 高空輻射探測

天文台在二零二零年進行了共兩次高空輻射探測。進行探測時的天氣情況如下：三月十九日多雲，地面吹輕微偏東風。五月七日部分時間有陽光，地面吹和緩偏南風。

大氣中高度低於 60 公里的輻射主要來自宇宙射線，而高度低於 4 公里的輻射則源自地面(即土壤和岩石)。當高能量宇宙射線從外太空進入大氣時，它們會與空氣中的原子和分子發生相互作用而產生次級宇宙射線。當次級宇宙射線在某一高度的產生，跟吸收和衰減達至平衡時，在該高度便會出現輻射的鋒值。

圖 7 為二零二零年高空輻射探測的平均大氣放射性垂直廓線，圖中顯示伽馬加貝他計數率及伽馬計數率從地面至約 500 米高度迅速減少，這是由於受陸地土壤或岩石等天然輻射的影響隨高度迅速降低所致。兩計數率從約 2 公里高度以上開始增加，大概至 16 公里高度分別達至 2.0 及 4.4(每秒計數)的鋒值，計數率在隨後的高度開始減少。前述數據分析結果顯示，與以往結果大致相若(*李新偉等，2007*)。

在 10 公里高以上的中高層大氣，由於伽馬和貝他輻射源自天然本底輻射，因此伽馬加貝他計數率及伽馬計數率的比值普遍穩定，如大氣中有異常的人工放射性物質，該比值便有機會出現變化。至於在 10 公里高以下的大氣，因為計數率低及測量誤差大，所以在正常情況比值變化也甚大。

3.1.7 食物及環境樣本

二零二零年天文台共收集了 423 個常規食物和環境樣本。表 6、7、8 和 9 分別列載樣本的伽馬譜法分析、氚、鍶-90 及鈈-239 測量結果。

各表中只列出有關人工放射性核素的可測量活度結果。為方便參考，表 10 按不同的照射途徑臚列了二零二零年各主要樣本類別的測量結果。

活度數據均按照取樣日期進行衰變修正。倘若取樣工作持續進行了一段較長的時間（例如一週或一個月），衰變修正便會以取樣期間的中間日期作為依據。

(a) 伽馬譜法分析

二零二零年在部份食物、土壤及沉澱物樣本中發現微量的人工伽馬放射性核素銫-137，活度均在 BRMP 範圍之內。樣本包括海產、土壤、潮間帶土及海床沉澱物，在 BRMP 期間及過往 ERMP 的監測工作中也曾在這幾類樣本中發現銫-137（*黃明松等，2003*），相信主要是與一九四五至一九八零年間大氣核武試驗的沉降物殘餘有關(*UNSCEAR 2008*)。

(b) 氚

二零二零年在部份大氣、水及食物樣本中發現微量的氚，活度均在本底輻射範圍之內。樣本包括大氣水蒸氣、濕沉積物、總沉積物、地下水、海水、飲用水、樽裝水、食米、牛奶、水果、蔬菜、家禽、肉類、海產及海藻。所偵測到的氚相信主要是因宇宙射線自然產生，而小部份則是以往大氣核武試驗的殘餘(*UNSCEAR 2008*)。

(c) 鍶-90

二零二零年在部份大氣、食物及土壤樣本中發現微量的鍶-90，活度均在本底輻射範圍之內。這些樣本包括大氣飄塵、濕沉積物、總沉積物、土壤、蔬菜、水果、肉類、海產、海藻及海水中懸浮粒子。在 BRMP 期間及過往 ERMP 的監測工作中，這些樣本中也曾發現鍶-90，相信主要也是來自以往大氣核武試驗(*UNSCEAR 2008*)。

(d) 鈈-239

二零二零年在部份潮間帶土及海床沉澱物樣本中發現微量的鈈-239，活度均在 BRMP 範圍之內。鈈-239 主要也是來自以往大氣核武試驗的沉降物(*UNSCEAR 2008*)。

3.1.8 實驗室測量比對結果

在二零二零年七月，天文台參加了由 IAEA 所舉辦的測量能力測試，量度由 IAEA 所提供的一個水樣本內所含的放射性活度。IAEA 於同年十二月公佈了有關測試的個別實驗室評估報告，該報告顯示天文台的測量結果均在 IAEA 所公佈的可接受範圍之內。表 11 為天文台之測量結果。

同年十一月，天文台參加了政府化驗所安排就檢定奶粉樣本中銫-134 及銫-137 活度之實驗室比對。政府化驗所在同年十二月公佈比對結果，顯示天文台的測量結果與其他參與單位的數值吻合。表 12 為天文台之測量結果。

3.2 結論

除了於二零二零年十月五日早上短暫時間在京士柏測量到由於降雨而引致相對較高的輻射水平外，二零二零年在香港境內不同地點錄得的環境伽馬劑量率均在本底輻射範圍之內。與過去的情況相若，天文台在不同的環境及食物樣本中測量到微量的人工放射性核素，當中包括銫-137、氚、鍶-90 及鈈-239。它們的水平與在大亞灣核電站及嶺澳核電站運作之前所收集的樣本並沒有顯著分別。

總括而言，二零二零年香港的環境輻射水平及在環境和食物樣本中的人工放射性核素活度並沒有顯著變化。

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1. INTRODUCTION

Since 1961, the Hong Kong Observatory (HKO) has been monitoring environmental radiation levels in Hong Kong and participating in international programmes on environmental radiation monitoring organised by the International Atomic Energy Agency (IAEA) and the World Meteorological Organization (WMO).

In response to the construction of nuclear power stations at Daya Bay in Guangdong, the HKO embarked in 1983 on a comprehensive programme to monitor the environmental radiation levels in Hong Kong before and after the power plants commenced operation. The programme was named the "Environmental Radiation Monitoring Programme (ERMP)". It comprises two phases. The first phase spanned five years and is known as the "Background Radiation Monitoring Programme (BRMP)" and was conducted from 1987 to 1991 to establish the baseline radiation levels in Hong Kong prior to the operation of the Daya Bay Nuclear Power Station (Daya Bay NPS) in 1994. These baseline levels would help to reflect any changes arising from the operation of the nuclear power station. The monitoring results can be found in the report on the BRMP (*Hong Kong Observatory, 1992*).

The second phase of the ERMP, implemented since 1992 till now, contains all the essential features of the BRMP and with adjustments in sampling and measurement to take advantage of the experience gained and latest technological advancement. The ERMP is an on-going programme to detect long-term changes in environmental radiation levels in Hong Kong, if any, particularly those arising from the operation of the Daya Bay NPS and the Lingao Nuclear Power Station (Lingao NPS) since 1994 and 2002 respectively. Locations of nuclear power stations currently in Guangdong are shown in Figure 1.

The monitoring results of the ERMP can be found in the respective annual reports and summaries (https://www.weather.gov.hk/en/publica/pubrm.htm). Readers may refer to the relevant reports for details of the sampling, measurement and quality assurance work. From 2003 onwards, the annual reports are kept concise and only contain the most salient features of the programme, including summaries of measurement methods and results, highlights of new work, changes or measures introduced during the year.

Chapter 2 of this report describes the sampling schedule, the instruments and methods used for measuring ambient radiation levels and activity in food and environmental samples, as well as quality assurance. Measurement results of 2020 and conclusions are presented in Chapter 3.

2. SAMPLING, MEASUREMENT AND QUALITY ASSURANCE

The emphasis of the ERMP is to monitor three major exposure pathways, namely the atmospheric pathway, the terrestrial pathway and the aquatic pathway. In respect of measurement, there are two major components. The first component is the direct measurement of ambient radiation levels in Hong Kong. The second is the detection of artificial radioactive material in the environmental samples of Hong Kong and in the foodstuff commonly consumed by Hong Kong people. The locations for real-time measurement of ambient radiation in 2020 are shown in Figure 2. The other locations for measurement of ambient gamma radiation and collection of environmental samples in 2020 are shown in Figure 3. A summary of the sampling and analysis programme in 2020 is given in Table 1.

2.1 Direct measurement of ambient radiation level

2.1.1 Radiation Monitoring Network

The radiation monitoring network (RMN) of the Hong Kong Observatory comprises 12 monitoring stations distributed over different locations of the territory (Figure 2). The network provides a comprehensive coverage for measurement of ambient gamma radiation level in Hong Kong.

The dose rates are measured at each station continuously by a high pressure ionization chamber (HPIC) (Reuter-Stokes Model RSS-131/RSS-131-ER environmental radiation monitor). Data are transmitted to the Observatory Headquarters every minute via a dedicated government communication network and other data transmission channels. In 2020, the Observatory completed the installation of new model HPICs (Reuter-Stokes Model RS-S131-200 environmental radiation monitor) in all 12 monitoring stations and the new HPICs started trial operation progressively. It is expected that after smooth completion of the trial run, the new model HPICs will be put into operation in stages to replace existing HPICs.

The hourly average ambient gamma dose rate data recorded by the radiation monitoring stations are made available on the Internet for reference by the public. The address of the website is:

https://www.weather.gov.hk/en/radiation/monitoring/index.html

The Online Gamma Spectroscopic Analyzer Network (OGSAN) with online gamma spectroscopic analyzers installed in eight designated radiation monitoring stations commenced full operation in 2018 (Figure 2). The gamma spectroscopic analyzer, Model RS250 Gamma Monitoring System, is manufactured by Radiation Solutions Inc. It utilizes sodium iodide (NaI) detector for monitoring the ambient gamma-emitting radionuclides and radiation level in real time. Data from the gamma spectroscopic analyzer are transmitted to the Observatory Headquarters every minute. The spectral data will facilitate timely identification of abnormal presence of artificial gamma-emitting radionuclides, if any, in the environment, thus further enhancing the capability of emergency response and consequence assessment.

2.1.2 Thermoluminescent Dosimeter Network

A thermoluminescent dosimeter (TLD) network has been in operation since the late 1980s to measure ambient gamma doses accumulated over a long period. In 2020, the network comprises 29 fixed monitoring stations over the territory (Figure 3). The TLDs are of the lithium fluoride (LiF:Mg,Ti) and calcium fluoride (CaF_2:Dy) type (Harshaw 8807). A batch of five TLDs is placed at each station to ensure statistical accuracy. The TLDs are replaced and read on a quarterly basis.

2.1.3 Aerial Radiation Monitoring System

The Observatory started carrying out aerial radiation monitoring in 1998 and replaced the monitoring system in 2013. The current Aerial Radiation Monitoring System (ARMS) is manufactured by Pico Envirotec Inc. It consists of four 2.5 litres sodium iodide (NaI) detectors that can be mounted on board a helicopter of the Government Flying Service for measurement. The count rates so measured can facilitate the monitoring of environmental radiation level.

The ARMS can operate in the plume tracking mode, which has the capability to determine the existence and extent of any radioactive plume over Hong Kong. After the passage of the plume, the system, operated in the ground contamination measurement mode, can be used to identify surface areas contaminated by deposited radionuclides. Real-time location information, gamma spectra, spectroscopic analysis results, gamma dose rates, etc. are displayed on board the helicopter during monitoring operation.

In 2020, the Government Flying Service (GFS) started to operate the new model Airbus H175 Cheetah helicopter. Adjustments had to be made in the installation of the ARMS in response to the configuration of the new model helicopter. Instead of the original mounting location inside the helicopter cabin, the ARMS detectors were installed inside a black pod attached to the exterior of the helicopter. This change in the set-up enables the detectors to be more exposed to the surrounding environment, thereby increasing the detection efficiency of the environmental radiation level. Furthermore, since the new model helicopter is equipped with the satellite transmission system, radiation measurement data can be transmitted to the Observatory Headquarters in real time.

The merit of ARMS is that it can be used to detect radiation levels over remote areas and over regions inaccessible to land transportation. Every year, routine measurements are made using ARMS to collect data of environmental radiation level as well as to monitor the change in radiation levels against altitude.

2.1.4 Automatic Gamma Spectrometry System

Hong Kong Observatory has been operating the Automatic Gamma Spectrometry System (AGSS) at Ping Chau, Mirs Bay since 1996 (Figure 2) for providing early alert of any releases of artificial radionuclides from the nuclear power stations. The system consists of a zinc sulphide (ZnS) coated plastic scintillator, a high purity germanium (HPGe) detector and a NaI detector. It continuously collects airborne particulates on a rotating filter drum and gaseous iodine in a carbon cartridge. The flow rates of the filter drum and carbon cartridge are around 30 m^3/hour and 4 m^3/hour respectively. The carbon cartridge is replaced automatically at weekly intervals. Alpha and beta activities of the particulates are measured by the ZnS scintillator and then calculated. Gamma rays emitted by the particulates are measured by the HPGe detector and analysed automatically by a gamma spectrometry analyses software. The iodine-131 activity is measured by the NaI detector on the carbon cartridge.

Data of alpha and beta activities, iodine-131 activity, as well as results of gamma spectrometry analysis are transmitted to the Observatory Headquarters every 5 to 15 minutes.

The Observatory started the replacement work of the aforementioned system in 2018. After completion of testing and optimization, the new system was put into operation in September 2020. The operating principles between two systems are generally similar, while there are enhancements in the hardware and software design of the new system, which mainly include:

(a) a more reliable ion implanted silicon detector is used to replace the ZnS coated plastic scintillator for the measurement of alpha and beta activities of airborne particulates;

(b) a cassette type filter paper design is adopted to replace the rotating filter drum for the collection of airborne particulates, reducing the number of hardware parts and increasing the temporal resolution of gamma measurement. The flow rate of the filter is changed to 15 m^3/hour; and

(c) the updating frequency of all measurement data is unified to once every 10 minutes to facilitate analysis.

2.1.5 Mobile Radiation Monitoring Station

Currently the Observatory has two radiological survey vehicles for terrestrial radiation monitoring. A Mobile Radiation Monitoring Station (MRMS) is set up inside each survey vehicle. It is equipped with portable and tailor-made instruments for use in collecting samples as well as routine and emergency radiological surveys.

Major instruments are listed below:

Instrument	**Location**	**Usage**
Sodium Iodide Gamma Spectrometer (Alpha Spectra, Inc. 16D16X64SS/3.5)	Installed inside the vehicle	To identify artificial gamma-emitting radionuclides in the environment.
High Volume Air Sampler (Hi-Q Environmental Products) (flow rate at about 54 m^3h^{-1})		Air is drawn from outside into the samplers through an inlet on the vehicle roof.
Radioiodine Sampler (Hi-Q Environmental Products) (flow rate at about 4.8 m^3h^{-1})		
Gamma Dose Rate Probe (Seibersdorf SSM1-07)	Installed on the vehicle roof	The probe is connected to a portable survey meter inside the vehicle so that staff inside the vehicle can continuously take readings of the ambient gamma dose rate outside the station.
Portable High Pressure Ionization Chamber (HPIC) (Reuter-Stokes RSS-131/RSS-131-ER)	The HPIC is mounted inside the vehicle. It can also be dismounted from the vehicle and placed on survey site for measurements.	To measure the ambient gamma radiation level enroute when mounted inside the vehicle. When placed outside the vehicle at each measurement location, staff can mount the sensor of the HPIC at 1 metre above ground for measurement.
Portable Survey Meter (Seibersdorf SSM-1)	The instruments are stored inside the vehicle and will be transported to survey site for measurements.	Equipped with Geiger Müller tube to measure ambient gamma dose rate.
Surface Contamination Monitor (Berthold Technologies LB-124)		Equipped with a ZnS scintillator. Staff uses the Surface Contamination Monitor to take alpha, beta and gamma surface contamination measurements at 1 cm above the surface.
Portable Gamma Spectrometric Analysis Module (Canberra In-Situ Object Calibration System/HPGe detector)		For ambient gamma spectrometric analysis at survey location.

In addition, meteorological instruments are installed on the roof of both vehicles to collect weather data like wind direction, wind speed, temperature and humidity. Cameras are also installed for monitoring the environment.

The radiological survey vehicles are deployed for routine radiological survey, collection of samples and emergency drills. They also pay regular visits to selected locations in Hong Kong to collect environmental radiation data.

2.1.6 Upper-air Radioactivity Soundings

Radioactivity in the upper atmosphere is measured at King's Park by radioactivity sensors attached to balloon-borne radiosondes (Model Meisei RS-06G). The radioactivity sensor (Model Meisei MNS-13) comprises two Geiger-Müller (GM) tubes: a gamma-only tube, which measures only gamma radiation, and a gamma-plus-beta tube, which measures gamma as well as beta radiation of energy higher than 0.25 MeV. The gamma-only tube has higher radiation detection efficiency than the gamma-plus-beta tube. Data from the radioactivity sensor is transmitted back and processed by the upper-air sounding system at the ground station.

The Observatory carries out regular radioactivity soundings under different weather conditions each year to collect data of the variation of radiation levels with altitudes.

2.2 Collection of food and environmental samples

2.2.1 Atmospheric Samples

Atmospheric samples, including airborne particulates, wet deposition (precipitation), total deposition (wet plus dry deposition), gaseous iodine and water vapour, are collected under ERMP. The sampling equipment and method are listed below:

Atmospheric Samples	**Sampling Equipment**	**Flow Rate**	**Sampling Method**
Airborne Particulates	High Volume Air Sampler (Hi-Q Environmental Products Model 4200 AFC-BRL-KIT/230, BRL-3000M and HVP 4300 AFC)	Typically set at 17 m^3h^{-1}	Routine weekly airborne particulate sample is collected from a filter paper installed inside the High Volume Air Sampler.
	Enhanced High Volume Air Sampler (F&J Specialty Products Model UHV-600)	Typically set at 800 m^3h^{-1}	Airborne particulate sample is collected from a filter paper installed inside the Enhanced High Volume Air Sampler, when needed.
Wet Deposition	A carboy fitted with a top funnel.	-	One set of carboy and funnel is placed at each location to collect rain for measurement. During dry season, three sets will be placed to collect more rain.

Atmospheric Samples	**Sampling Equipment**	**Flow Rate**	**Sampling Method**
Total Deposition	A stainless-steel pan of 260 mm diameter filled with distilled water.	-	Samples are collected at weekly interval.
Gaseous Iodine	Sampled through a silver impregnated zeolite cartridge fitted inside a radioiodine sampler (Hi-Q Environmental Products Model CMP-0523CV/230).	Typically set at 2.5 m^3h^{-1}	The cartridge is collected and replaced weekly.
	TEDA (triethylene di-amine) impregnated carbon cartridge included in Enhanced High Volume Air Sampler (F&J Specialty Products Model UHV-600)	Typically set at 7.0 m^3h^{-1}	The cartridge is used to collect gaseous iodine samples, when needed.
Water Vapour	Collected using a gaseous effluent sampler (Pylon Electronics Inc. Model VFP-20) with a drierite cartridge.	Typically set at 0.12 m^3h^{-1}	Sampling is done intermittently during a week-long period randomly selected in each calendar month, until the overall collection time reaches 36 hours.

Airborne particulates and wet depositions are regularly collected at King's Park, Sha Tau Kok and Yuen Ng Fan (Figure 3) at weekly intervals. In addition, equipment is also installed at the other nine radiation monitoring stations for collecting atmospheric samples during emergency. Total deposition, gaseous iodine and water vapour are also collected at King's Park. During emergency and drills, the enhanced high volume air sampler will also be used to collect larger volume of airborne particulate samples, thus increasing the measurement efficiency.

2.2.2 Food Samples

Terrestrial and aquatic food samples typical of the diet of the local population are collected at main distribution points, wholesale markets and from enlisted suppliers. Particular attention has been given to food produced locally and in Shenzhen.

2.2.3 Drinking Water, Underground Water and Sea Water

Treated drinking water is collected from distribution taps at Kowloon and Tuen Mun as well as the water treatment works at Sha Tin, Tuen Mun and Yau Kom Tau (Figure 3). Untreated (raw) drinking water is collected from the High Island Reservoir, the Plover Cove Reservoir, the Muk Wu B Pumping Station and the water treatment works at Sha Tin, Tuen Mun and Yau Kom Tau (Figure 3). Both treated and untreated drinking water samples are collected once every three months by staff of the Water Supplies Department. The drinking water samples are passed to the Observatory for radiological measurements.

Underground water# is collected at five locations (Figure 3), namely Cheung Hong Estate (Tsing Yi), Wan Tsui Estate (East Hong Kong Island), Wah Fu Estate (Pokfulam), Fu Shan Estate (East Kowloon) and Ching Leung Nunnery (Tuen Mun) in 2020 with assistance from the Housing Department, the respective estate management and the nunnery personnel.

Each quarter, with the assistance from the Environmental Protection Department, sea water is sampled alternately at two of four routine sampling locations. The four routine sampling locations are over the eastern part of the coastal waters of Hong Kong (Figure 3), namely waters off Waglan Island, Basalt Island, Tai Long Wan and Port Island. At each location, samples are collected at three depths – the upper level (2.5 metres underneath the surface), the middle level (equidistant from the surface and the seabed) and the lower level (2.5 metres above the seabed). Suspended particulates in sea water are collected by filtering the sea water samples through a membrane filter.

2.2.4 Land Soil and Sediments

Land soil is sampled at 39 designated sites throughout the territory. Each site is sampled once every five years. At each site, samples were collected from two layers, the upper layer from the surface to 15 cm deep and the lower layer from 15 cm to 30 cm deep. In 2020, land soil samples were collected from King’s Park, Sha Tin, Sai Kung, Clear Water Bay, High Island West, High Island East, Pak Tam Au and Pak Sha O (Figure 3).

Intertidal sediments are sampled quarterly at three locations along the coast of Hong Kong (Figure 3), namely Pak Sha Wan, Tsim Bei Tsui and Sha Tau Kok. Two layers are taken at each sampling point, the upper layer from the surface to 15 cm deep and the lower layer from 15 cm to 30 cm deep. Sampling of seabed sediments is carried out annually with the assistance of the Civil Engineering and Development Department at four locations (Figure 3), namely Tai Tan Hoi, Lung Ha Wan, Picnic Bay and Western Anchorage.

The sampling and analysis programme in 2020 is summarized in Table 1.

2.3 Measurement of food and environmental samples in laboratory

After treatment, all activity measurements of food and environmental samples are carried out in the Radiation Laboratory at King’s Park.

A list of the major artificial radionuclides routinely monitored is given in Table 1.

As the underground water pumping system at Yuen Long stopped opearation, the number of sampling locations of underground water has been reduced from six to five since 2019. Owing to the change in land use pattern and environment, finding suitable sampling location for underground water has become difficult. The Observatory will regularly review the situation of sites for sampling in Hong Kong.

Each sample, depending on the sample type and measurement objective, will go through one or more of the following analyses:

(a) Gamma spectrometry analysis
The activities of gamma-emitting radionuclides are determined by using a gamma spectrometry system which consists of six high purity germanium (HPGe) detectors. The Observatory replaced two HPGe detectors and the related digital signal analyzers in 2020. The remaining detector and hardware are expected to be replaced in 2021. Currently, five detectors are manufactured by Ortec and the other one by Mirion (formerly Canberra). Among the HPGe detectors, four of them are cooled by liquid nitrogen, complemented by two other detectors manufactured by Ortec cooled by electric system.

(b) Liquid scintillation counting
The activity of tritium† is measured by a liquid scintillation counting system (TriCarb 3170 TR/SL) manufactured by Perkin Elmer. Replacement work of the system commenced in 2020. The new system is expected to become operational in 2021.

(c) Low-level gross beta counting
The activity of strontium-90 is measured by a low level alpha-beta counting system. The model of the system currently in operational use is Berthod LB790, while the model of the backup system is Berthod LB770-2.

(d) Alpha spectrometry analysis
The activity of plutonium-239 is measured by an alpha spectrometry system. The model of the system currently in operational use is Ortec Alpha Ensemble, while the model of the backup system is EG&G Ortec OCTETE PC.

A summary of key measurement parameters, including sample size, counting time and detection limits, are given in Table 2.

2.4 Comparison between BRMP and ERMP measurement results

Among the radiation measurements described in Section 2.1 to 2.3, some of the radiation monitoring stations, the Automatic Gamma Spectrometry System as well as radiological measurements of some of the environmental and food samples had not yet started operation during the BRMP 5-year period. Hence, for the measurement results from these systems or samples, no corresponding BRMP ranges are available as background reference.

†Tritium is primarily produced naturally by cosmic rays entering the atmosphere or generated during atmospheric nuclear weapon tests conducted from 1945 to 1980. A small amount is also produced during the operation of nuclear power stations (*UNSCEAR 2008*).

Despite this, during the years of operation since the start of the second phase of ERMP in 1992, long term results of BRMP-covered radiation measurement of ambient radiation levels and activities of artificial radionuclides suggested that there had been no material changes in the overall environmental radiation levels in Hong Kong as a result of the operation of the nuclear power plants (*Kong Y.C. and Olivia S.M. Lee 2017*). On this basis, for radiation measurement without BRMP reference values (i.e. measurement started after the second phase of ERMP), the range of values in the first five years of measurement were adopted as the reference range in this report. This reference range, being closest to the BRMP period in time, can effectively be taken as the approximate baseline level of that radiation measurement in the absence of visible influences from other variables.

2.5 Quality assurance

Since 1989, the Observatory has been participating in inter-laboratory comparison exercises and proficiency tests organised by international and national organisations (*Hui et al., 2007*), namely the International Atomic Energy Agency (IAEA), the National Physical Laboratory of the United Kingdom (NPL), the World Health Organization (WHO) and the China Institution for Radiation Protection (CIRP). In recent years, the Observatory also participated in the comparison exercises organised by the China Institute of Atomic Energy (CIAE), the Shanghai Radiation Environmental Supervision Station (ShRESS) and the Government Laboratory (GL).

In July 2020, the Observatory participated in a laboratory proficiency test organised by IAEA for the measurement of activities of radionuclides in water sample. In November of the same year, the Observatory also joined the inter-laboratory comparison organised by the Government Laboratory on the determination of activities of caesium-134 and caesium-137 in milk powder sample. Details can be found in Section 3.1.8.

Other than inter-laboratory comparison exercises and proficiency tests, the quality of the environmental radiation monitoring results in Hong Kong is also assured through internal quality assurance procedures.

To enhance the management efficiency and quality of radiation measurement work, the management procedures of the King’s Park Radiation Laboratory’s radiation measurement service and the Ambient Gamma Radiation Level Measurement Service both adhere to the standards based on the International Organisation for Standardization ISO 9001 in their operations. The aforesaid two services successfully obtained certifications for ISO 9001:2008 in early 2009 and late 2015 respectively. Following the release of ISO 9001:2015, the Observatory further enhanced the management procedures of the two services. Radiation Laboratory’s measurement service and Ambient Gamma Radiation Level Measurement Service successfully passed the ISO 9001:2015 certification audits in 2017 and 2018 respectively.

The certification body regularly conducts surveillance audits of the aforesaid radiation measurement services to ascertain that the services meet the requirements for the continuation of ISO 9001:2015 certification. The quality of radiation measurement services provided by the Radiation Laboratory and the Ambient Gamma Radiation Level Measurement Service was reaffirmed upon their successful completion of the annual surveillance audits in 2020.

3. MEASUREMENT RESULTS AND CONCLUSION

3.1 Measurement results

3.1.1 Radiation Monitoring Network

The annual average ambient gamma dose rates and ranges of 1-minute averages recorded by the RMN in 2020 are tabulated in Table 3a.

Since the operation of the RMN, temporal changes in the radiation level recorded at the stations are typically a few per cent in seasonal variations. However, during rainy condition or episodes of tropical cyclone affecting Hong Kong, the variations can be significantly larger and may be a couple of times higher than the level at other times.

The most significant change in the ambient gamma dose rate in 2020 was recorded on 5 October. Under the influence of thundery showers associated with a cold front in the morning, the 1-minute average dose rates at Ping Chau and King's Park rose to about double of their respective mean values of the year. The 1-minute average dose rate of 0.281 $\mu Gy\ h^{-1}$ recorded at King's Park also slightly exceeded the baseline radiation levels (see Table 3a for the reference range).

OGSAN and RMN complement each other in that when RMN registers a large variation in radiation level, the OGSAN can be used to determine whether the changes are brought by artificial gamma-emitting radionuclides. The ambient dose equivalent rate data recorded by the gamma spectroscopic analyzers at Ping Chau and King's Park also showed significant change on 5 October 2020. Nonetheless, no artificial gamma-emitting radionuclides were detected in the spectroscopic analyses. Hence the higher radiation level recorded on that day was brought by rain washing down the natural gamma-emitting radionuclides to ground level.

Apart from the aforesaid case, the ambient radiation levels as measured by the radiation monitoring network in 2020 were all within baseline radiation levels.

3.1.2 Thermoluminescent Dosimeter Network

The annual average, standard deviation and variation of gamma dose rates measured at each of the TLD stations in 2020 are listed in Table 3b. The gamma dose rates recorded at all stations were found to be within the BRMP range.

3.1.3 Aerial Radiation Monitoring System

In 2020, background measurements in the ground contamination measurement mode were conducted in April, June, September and November using the Aerial Radiation Monitoring System (ARMS) over Ping Chau, Tap Mun, Soko Islands and Kat O respectively. The measurement height followed terrain, maintaining at a height of about 100 metres above the ground. No artificial radionuclides were detected and measurement results obtained were similar to those in the past. Figure 4 shows the ambient radioactivity count rates over the areas on the days of measurements.

The Observatory used the plume tracking mode to carry out measurements of vertical radiation level profiles over Mirs Bay and Sai Kung in February 2020. The helicopter rose from about 100 metres up to about 1000 metres above sea level to measure the change of radiation levels against altitude. No artificial radionuclides were detected. Figure 5 depicts the vertical radiation level profiles over Mirs Bay and Sai Kung.

Similar to past observations, the count rates over waters of Mirs Bay showed no significant changes with height and reflected basically the background radiation levels.

As to the vertical radiation level profiles over Sai Kung, similar to past observations, the count rates measured near land surface were significantly higher than those measured over the sea surface, as rocks and soil contained more radioactive substances than sea water. The count rates over land decreased rapidly with height before reaching a level close to those measured over the sea.

3.1.4 Automatic Gamma Spectrometry System

Results obtained by the AGSS in 2020 are given in Table 4. No artificial radionuclides were detected in the year and all results were within ranges of environmental radiation levels.

3.1.5 Mobile Radiation Monitoring System

Four measurements of cosmic radiation were carried out at Plover Cove in 2020. The average gamma dose rates ranged from 0.032 to 0.035 μGy h^{-1} (Table 5), close to those measured in previous years.

Since 2017, the Observatory has deployed two radiological survey vehicles with portable high pressure ionization chambers onboard to carry out enroute radiation measurement along some major roads in the territory every year (see Figure 6 for the survey routes). In 2020, the two survey vehicles conducted a total of 160 surveys. In summary, the enroute ambient gamma dose rate recorded in 2020 ranged from 0.060 to 0.223 μGy h^{-1}, similar to measurement results on the same survey routes in the past.

The variations of ambient gamma radiation level are generally caused by the buildings, rock and soil, etc in the vicinity of measurement locations as well as the weather conditions during measurements. Figure 6 shows the enroute gamma dose rate recorded along survey routes and the annual average values recorded by the Radiation Monitoring Network and Thermoluminescent Dosimeter Network in 2020.

3.1.6 Upper-air Radioactivity Soundings

Two radioactivity soundings were made in 2020. The weather conditions during these soundings were: cloudy with light easterly winds at the surface on 19 March and sunny periods with moderate southerly winds at the surface on 7 May.

The major source of radioactivity in the atmosphere below the altitude of 60 km is cosmic rays, whereas the atmosphere below 4 km height is dominated by terrestrial sources (i.e. soil and rock). When high-energy cosmic rays enter the atmosphere from the outer space, they interact with atoms and molecules in the air and generate secondary cosmic rays. A maximum in the radioactivity occurs at an altitude where the generation of secondary cosmic rays is balanced by lose processes such as absorption and decay.

Figure 7 is the average vertical profiles of atmospheric radioactivity from the upper-air radioactivity soundings in 2020. We can see that the gamma plus beta count rates and the gamma count rates decreased sharply from the ground surface to a height of about 500 m due to rapid reduction with height in the influence of terrestrial radiation from soil and rocks. Both count rates started to increase with height from about 2 km above the ground until reaching a maximum of 2.0 and 4.4 counts per second (cps) respectively at around 16 km height. Above this height, the count rates started to decrease. The aforesaid data analysis results obtained were similar to those in the past (*Li et al. 2007*).

In the middle to upper atmosphere above 10 km height, as gamma and beta radiation originates from natural background radiation, the ratio of gamma plus beta to gamma count rates is generally stable. If there are abnormal artificial radioactive materials present in the atmosphere, the ratio may fluctuate accordingly. In the atmosphere below 10 km height where count rates are low and measurement uncertainties are high, the ratio can vary considerably under normal circumstances.

3.1.7 Food and Environmental Samples

A total of 423 routine food and environmental samples were collected in 2020. The results of gamma spectrometry analyses, tritium measurements, strontium-90 measurements and plutonium-239 measurements are shown in Tables 6, 7, 8 and 9 respectively.

Only results pertaining to measurable activities of artificial radionuclides are included in all tables. For ease of reference, a summary of measurement results in 2020 for the major sample types according to different pathways is given in Table 10.

All activity data are decay-corrected to the date of sampling. Where sampling is done over an extended period (for instance a week or a month), decay correction is made with reference to the mid-point of the sampling period.

(a) Gamma Spectrometry Analyses

Traces of caesium-137, an artificial gamma-emitting radionuclide, were detected in some food, soil and sediment samples in 2020. The measured activities in these samples were all within the corresponding ranges of BRMP values. The samples included seafood, land soil, intertidal sediment and seabed sediment. Caesium-137 was detected in such sample types during BRMP and ERMP so far (*Wong et al. 2003*). The presence of the radionuclide in environmental and food samples could generally be attributed to the remnants of fallout from atmospheric nuclear weapon tests conducted from 1945 till 1980 (*UNSCEAR 2008*).

(b) Tritium

Very small amounts of tritium were detected in some atmospheric, water and food samples in 2020. The measured activities in these samples were all within the baseline radiation levels. The samples included water vapour in air, wet deposition, total deposition, underground water, sea water, drinking water, bottled water, rice, milk, fruits, vegetables, poultry, meat, seafood and seaweed. The source of tritium in the samples was attributable primarily to the natural cosmogenic processes with small contribution from the remnants from past atmospheric nuclear weapon tests *(UNSCEAR 2008*).

(c) Strontium-90

Traces of strontium-90 were detected in some atmospheric, food and soil samples in 2020. The measured activities in these samples were all within the baseline radiation levels. The samples included airborne particulates, wet deposition, total deposition, land soil, vegetables, fruits, meat, seafood, seaweed and suspended particulates in sea water. Strontium-90 was detected in such sample types in both BRMP and ERMP. The radionuclide's presence was also primarily attributable to atmospheric nuclear tests in the past (*UNSCEAR 2008*).

(d) Plutonium-239

Minute amounts of plutonium-239 were detected in some intertidal sediment and seabed sediment samples in 2020. The measured activities in these samples were all within the BRMP range. Fallout from past atmospheric nuclear weapon tests could again be the major source of plutonium-239 (*UNSCEAR 2008*).

3.1.8 Results of Laboratory Measurement Comparisons

In July 2020, the Observatory participated in a proficiency test organised by IAEA to measure the radioactivities in water sample. IAEA released the evaluation report for each participating laboratory in December 2020. The report confirmed that the measurement results of the Observatory were all within the acceptable ranges as announced by IAEA. The Observatory's measurement results are given in Table 11.

In November 2020, the Observatory participated in the inter-laboratory comparison organised by the Government Laboratory on the determination of activities of caesium-134 and caesium-137 in milk powder sample. Government Laboratory released the comparison report in December of the same year. The report revealed that the measurement results of the Observatory agreed with those reported by other participants. The Observatory's measurement results are given in Table 12.

3.2 Conclusion

Apart from the relatively high radiation levels recorded at King's Park for a short period of time due to rainy weather on the morning of 5 October 2020, the ambient gamma dose rates recorded over various parts of the territory in 2020 were within the baseline radiation levels. As in the past years, traces of artificial radionuclides, including caesium-137, tritium, strontium-90 and plutonium-239, were detected in various environmental and food samples. The levels of all these radionuclides were not significantly different from those recorded before the Daya Bay Nuclear Power Station and Lingao Nuclear Power Station came into operation.

It is concluded that in 2020 there was no significant change in ambient radiation levels and the activities of artificial radionuclides in the Hong Kong environment and foodstuffs consumed by Hong Kong people.

ACKNOWLEDGEMENT

The Hong Kong Observatory wishes to express its gratitude to the Agriculture, Fisheries and Conservation Department, Civil Engineering and Development Department, Environmental Protection Department, Water Supplies Department and Housing Department for their assistance in sample collection, the Government Laboratory for chemical treatment of samples, and the Department of Health for providing and reading thermoluminescent dosimeters. We would also like to express our appreciation to the Government Flying Service for the operation of the Aerial Radiation Monitoring System together with the Observatory, and the Hong Kong Police Force for providing accommodation at police stations to a number of radiation monitoring stations and the Automatic Gamma Spectrometry System. Special thanks also go to government offices and various organisations for giving us permission to install thermoluminescent dosimeters and to collect samples within their premises.

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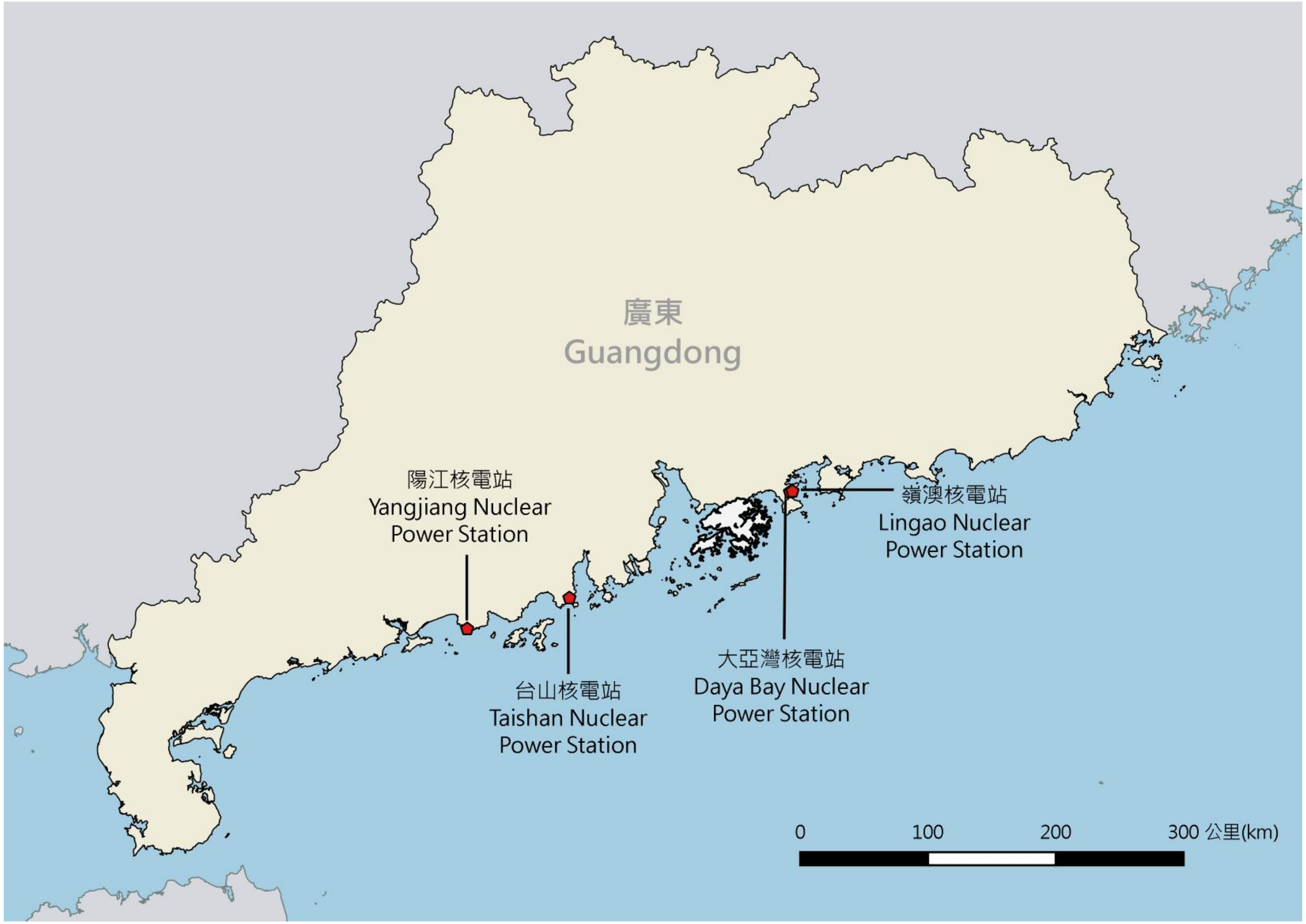

圖 1.　　廣東省核電站位置分佈圖。

Figure 1.　　Locations of nuclear power stations in Guangdong.

圖 2. 二零二零年實時監測環境輻射的測量點。

Figure 2. Locations for real-time measurement of ambient radiation in 2020.

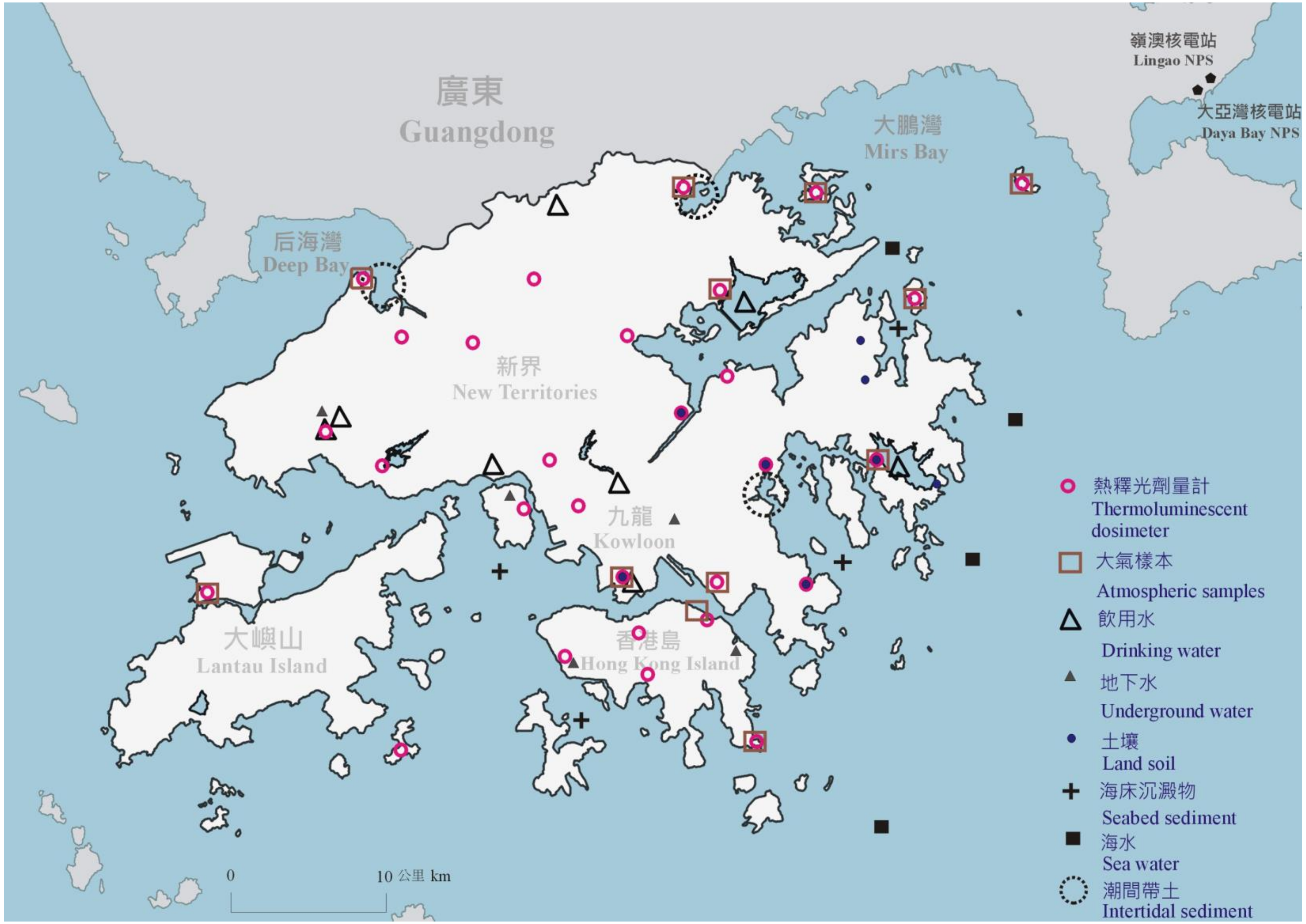

圖 3. 熱釋光劑量計網絡及二零二零年環境樣本收集點。

Figure 3. Thermoluminescent dosimeter network and collection points of environmental samples in 2020.

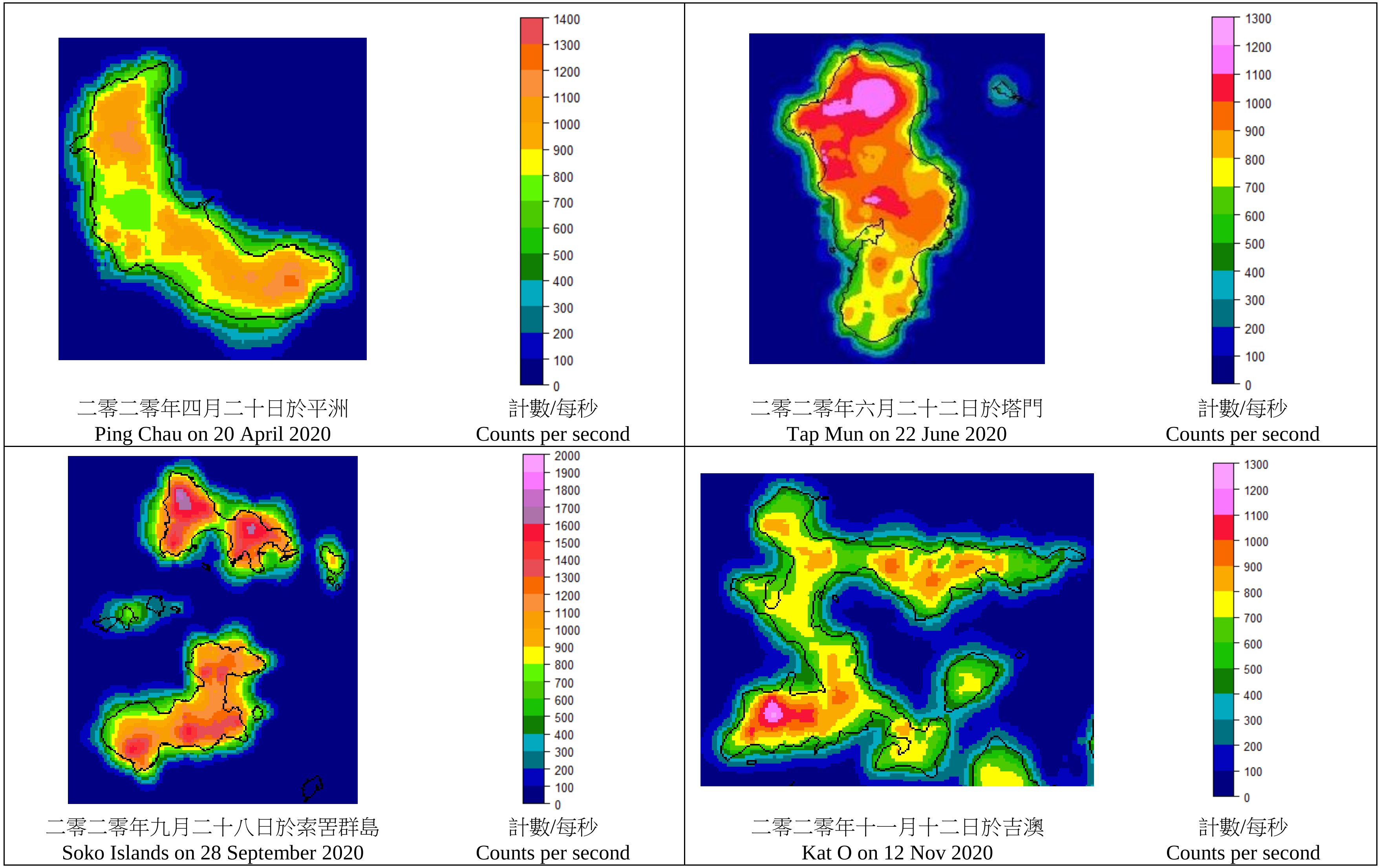

圖 4. 空中輻射監測系統在二零二零年分別於平洲、塔門、索罟群島和吉澳測量的計數率(測量高度距離地面約一百米)。

Figure 4. Count rate over Ping Chau, Kat O, Soko Islands and Tap Mun respectively as measured by the Aerial Radiation Monitoring System in 2020 (at about 100 metres above the ground).

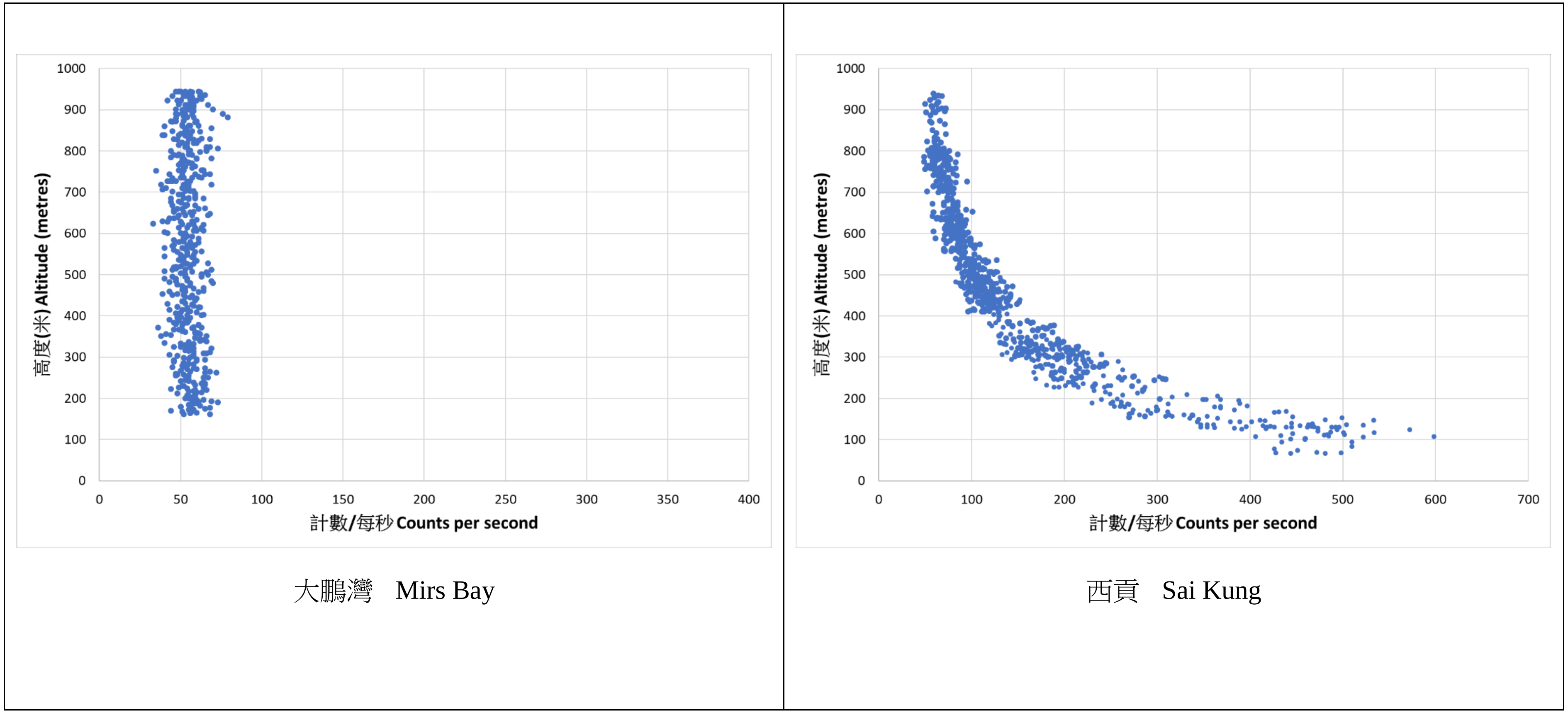

圖 5. 空中輻射監測系統在二零二零年二月二十五日於大鵬灣海面及西貢上空測量的計數率隨高度的變化。

Figure 5. Variation of count rate with altitude over Mirs Bay and Sai Kung area, as measured by the Aerial Radiation Monitoring System on 25 February 2020.

[數據的分佈密度會根據直升機爬升速度而有所變化。]
[The density of data will vary with the climbing speed of the helicopter.]

圖 6. 二零二零年流動輻射監測站、輻射監測網絡及熱釋光劑量計網絡錄得的環境伽馬劑量率。

Figure 6. Ambient gamma dose rate recorded by the Mobile Radiation Monitoring Station, the Radiation Monitoring Network and the Thermoluminescent Dosimeter Network in 2020.

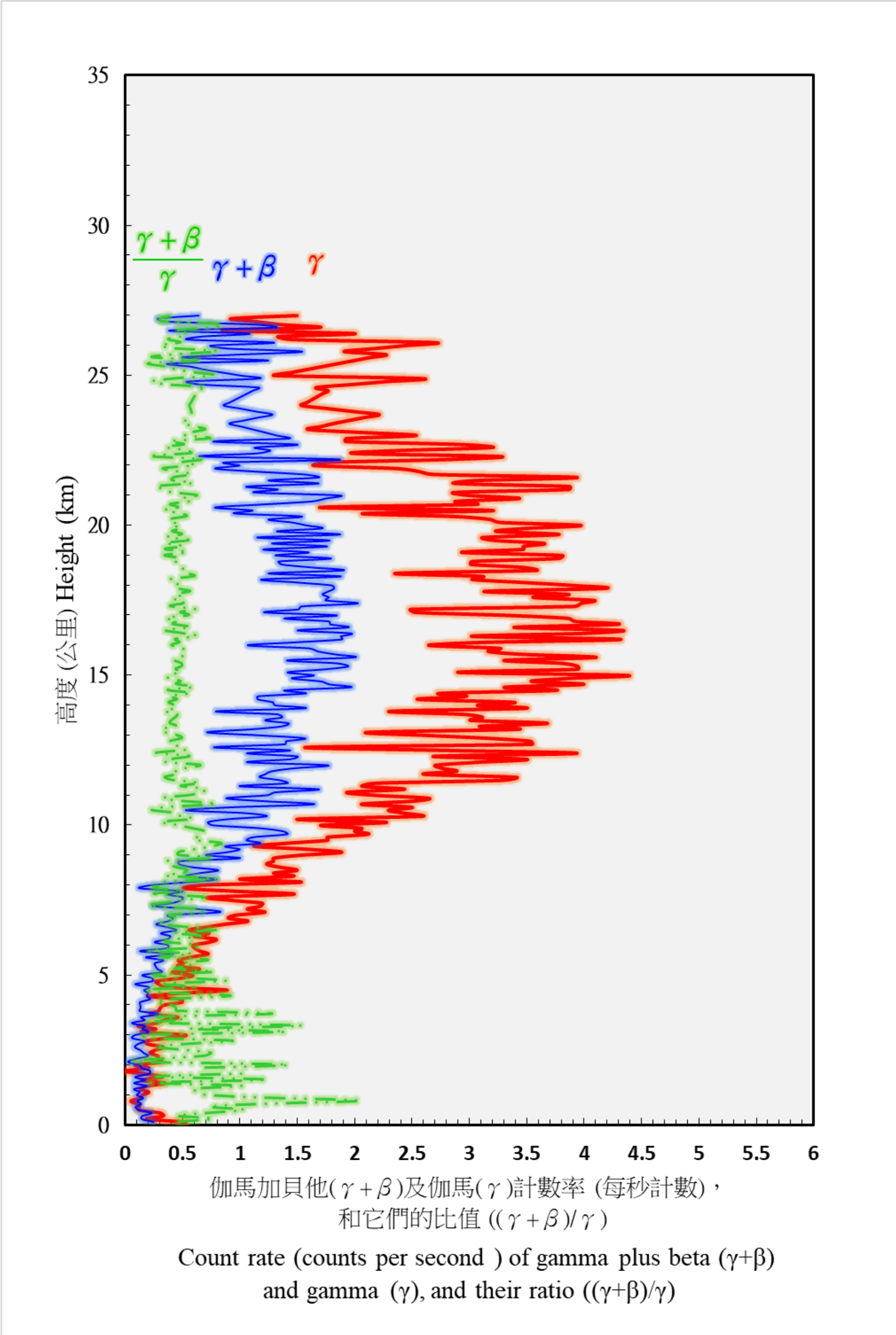

圖 7. 二零二零年內在京士柏進行的高空輻射探測之平均大氣放射性垂直廓線(探測日期為：三月十九日及五月七日)。

Figure 7. Average vertical profiles of atmospheric radioactivity from upper-air radioactivity soundings conducted at King's Park in 2020 (dates of sounding: 19 March and 7 May).

表 1.　　二零二零年樣本取樣及分析概要

Table 1.　Summary of the sampling and analysis programme in 2020

樣本類別 **Sample type**	取樣地點 **Sampling location**	地點數目 **Number of location**	分析類別 **Type of analysis**	取樣頻率 **Sampling frequency**
環境伽馬輻射 Ambient Gamma Radiation				
伽馬劑量率 Gamma dose rates	平洲 Ping Chau, 塔門 Tap Mun, 吉澳 Kat O, 沙頭角 Sha Tau Kok, 元五墳 Yuen Ng Fan, 大美督 Tai Mei Tuk, 尖鼻咀 Tsim Bei Tsui, 觀塘 Kwun Tong, 西灣河 Sai Wan Ho, 京士柏 King’s Park, 鶴咀 Cape D’Aguilar, 赤鱲角 Chek Lap Kok	12	伽馬 γ	一分鐘 1-minute interval
累積伽馬劑量 Cumulative gamma doses	平洲 Ping Chau, 塔門 Tap Mun, 吉澳 Kat O, 元五墳 Yuen Ng Fan, 清水灣 Clear Water Bay, 西貢 Sai Kung, 大美督 Tai Mei Tuk, 烏溪沙 Wu Kai Sha, 鶴咀 Cape D’Aguilar, 沙頭角 Sha Tau Kok, 沙田 Sha Tin, 觀塘 Kwun Tong, 筲箕灣 Shau Kei Wan, 大埔 Tai Po, 京士柏 King’s Park, 跑馬地 Happy Valley, 深水灣 Deep Water Bay, 石梨貝 Shek Lei Pui, 置富花園 Chi Fu Fa Yuen, 粉嶺 Fanling, 荃灣 Tsuen Wan, 石崗 Shek Kong, 長洲 Cheung Chau, 元朗 Yuen Long, 大欖涌 Tai Lam Chung, 尖鼻咀 Tsim Bei Tsui, 屯門 Tuen Mun, 赤鱲角 Chek Lap Kok, 青衣 Tsing Yi	29	伽馬 γ	每季 quarterly

表1. (續)
Table 1. (cont'd)

樣本類別 **Sample type**	取樣地點 **Sampling location**	樣本數目 **Number of samples[(1)]**	分析類別 **Type of analysis**	取樣頻率 **Sampling frequency**
大氣樣本 Atmospheric Samples				
大氣飄塵 Airborne particulate	京士柏 King's Park	12 (每月樣本 Monthly bulked sample)	伽馬 γ, 鍶-90 Sr-90, 鈈-239 Pu-239	每週樣本進行初步伽馬分析，累積每月樣本進行全面分析 preliminary γ analysis of weekly samples, full analysis for bulked monthly sample
	沙頭角 Sha Tau Kok			
	元五墳 Yuen Ng Fan			
濕沉積物(降雨) Wet deposition (precipitation)	京士柏 King's Park	10 (每月樣本 Monthly bulked sample)	伽馬γ, 氚 H-3, 鍶-90 Sr-90, 鈈-239 Pu-239	每週取樣，但累積每月樣本作全面分析 weekly samples, bulked monthly for full analysis
	沙頭角 Sha Tau Kok			
	元五墳 Yuen Ng Fan			
總沉積物 Total deposition	京士柏 King's Park	12		
氣態碘 Gaseous iodine		52	伽馬 γ	每週 weekly
大氣水蒸氣 Water vapour in air		12	氚 H-3	每月 monthly
地面樣本 Terrestrial Samples				
食米 Rice	內地(珠江三角洲) Mainland (Pearl River Delta)	4	伽馬γ, 氚 H-3, 鍶-90 Sr-90	每季 quarterly
牛奶(經消毒) Pasteurized milk	內地(深圳/惠州) Mainland (Shenzhen/Huizhou)	8		
菜心 Choi sum	內地(深圳) Mainland (Shenzhen)	4		
	本地 Local	4		
白菜 Pak choi	內地(深圳) Mainland (Shenzhen)	4		
	本地 Local	4		
香蕉 Banana	內地(廣東) Mainland (Guangdong)	4		
荔枝 Lychee	內地(廣東) Mainland (Guangdong)	1		夏季 summer
柑橘 Mandarin	內地(廣東) Mainland (Guangdong)	2		秋季及冬季 autumn and winter
甘蔗 Sugar cane	內地(廣東) Mainland (Guangdong)	1		春季 spring
雞 Chicken	內地(深圳) Mainland (Shenzhen)	4		每季 quarterly
	本地 Local	4		
鴨 Duck	內地(深圳) Mainland (Shenzhen)	4		
牛肉 Beef	內地(廣東) Mainland (Guangdong)	4		
豬肝 Pig's liver	內地(廣東) Mainland (Guangdong)	4		
	本地 Local	4		
豬肉 Pork	內地(廣東) Mainland (Guangdong)	4		
	本地 Local	4		

表1. (續)
Table 1. (cont'd)

樣本類別 **Sample type**	取樣地點 **Sampling location**	樣本數目 **Number of samples[(1)]**	分析類別 **Type of analysis**	取樣頻率 **Sampling frequency**
土壤 (上層及下層) Land soil (upper and lower level)	京士柏 King's Park*, 沙田 Sha Tin*, 西貢 Sai Kung*, 清水灣 Clear Water Bay*, 萬宜水庫西 High Island West*, 萬宜水庫東 High Island East*, 北潭凹 Pak Tam Au*, 白沙澳 Pak Sha O*, 大埔 Tai Po, 粉嶺 Fanling, 沙頭角 Sha Tau Kok, 大美督 Tai Mei Tuk, 城門水塘 Shing Mun Reservoir, 荃灣 Tsuen Wan, 大欖涌水塘 Tai Lam Chung Reservoir, 青山發電廠 Castle Peak Power Station, 元朗 Yuen Long, 尖鼻咀 Tsim Bei Tsui, 石崗 Shek Kong, 嘉道理農場暨植物園 Kadoorie Farm and Botanic Garden, 長洲 Cheung Chau, 南丫島 Lamma Island, 坪洲 Peng Chau, 銀礦灣 Silvermine Bay, 東涌 Tung Chung, 石壁水塘 Shek Pik Reservoir, 大澳 Tai O, 白泥 Pak Nai, 塔門 Tap Mun, 吉澳 Kat O, 平洲 Ping Chau, 跑馬地 Happy Valley, 薄扶林水塘 Pokfulam Reservoir, 香港仔下水塘 Lower Aberdeen Reservoir, 深水灣 Deep Water Bay, 大潭水塘 Tai Tam Reservoir, 鶴咀 Cape D'Aguilar, 牛頭角配水庫 Ngau Tau Kok Service Reservoir, 石梨貝水塘 Shek Lei Pui Reservoir	16	伽馬 γ, 鍶-90 Sr-90, 鈈-239 Pu-239	每一地點每 5 年採樣一次 Each location is sampled once every 5 years. * 2020 年採樣地點 * locations sampled in 2020

表 1. (續)

Table 1. (cont'd)

樣本類別 **Sample type**	取樣地點 **Sampling location**	樣本數目 **Number of samples**[(1)]	分析類別 **Type of analysis**	取樣頻率 **Sampling frequency**
水體樣本 Aquatic Samples				
飲用水(經處理) Drinking water (treated)	九龍配水管 Kowloon distribution tap,	4	伽馬 γ, 氚 H-3	每季 quarterly
	屯門配水管 Tuen Mun distribution tap,	4		
	沙田濾水廠 Sha Tin Water Treatment Works,	4		
	屯門濾水廠 Tuen Mun Water Treatment Works,	4		
	油柑頭濾水廠 Yau Kom Tau Water Treatment Works	4		
飲用水(未經處理) Drinking water (untreated)	萬宜水庫 High Island Reservoir,	4		每季 quarterly
	船灣淡水湖 Plover Cove Reservoir,	4		
	木湖 B 抽水站 Muk Wu B Pumping Station,	4		
	沙田濾水廠 Sha Tin Water Treatment Works,	4		
	屯門濾水廠 Tuen Mun Water Treatment Works,	4		
	油柑頭濾水廠 Yau Kom Tau Water Treatment Works	4		
樽裝水(蒸餾水) Bottled water (Distilled)	本地 Local	4		每季 quarterly
樽裝水(礦泉水) Bottled water (Mineral)	本地 Local	4		每季 quarterly
地下水 Underground water	長康邨 Cheung Hong Estate,	1		每年 yearly
	環翠邨 Wan Tsui Estate,	1		
	華富邨 Wah Fu Estate,	1		
	富山邨 Fu Shan Estate,	1		
	清涼法苑 Ching Leung Nunnery	1		
海水(上層、中層及低層) Sea water (upper, middle and lower level)	橫瀾島 Waglan Island,	6		每季 quarterly
	火石洲 Basalt Island,	6		
	大浪灣 Tai Long Wan,	6		
	赤洲 Port Island	6		
海水中懸浮粒子 (上層、中層及低層) Suspended particulate in sea water (upper, middle and lower level)	橫瀾島 Waglan Island,	6	伽馬 γ, 鍶-90 Sr-90, 鈈-239 Pu-239	每季 quarterly
	火石洲 Basalt Island,	6		
	大浪灣 Tai Long Wan,	6		
	赤洲 Port Island	6		

表1. (續)
Table 1. (cont'd)

樣本類別 **Sample type**	取樣地點 **Sampling location**	樣本數目 **Number of samples[(1)]**	分析類別 **Type of analysis**	取樣頻率 **Sampling frequency**
水體樣本 Aquatic Samples				
大魚 *Aristichthys nobilis* (Big-head carp)	內地(深圳) Mainland (Shenzhen)	4	伽馬 γ, 氚 H-3, 鍶-90 Sr-90, 鈈-239 Pu-239	每季 quarterly
	元朗 Yuen Long	3		
瓜三 *Nemipterus japonicus* (Melon coat)	大亞灣 Daya Bay,	1		
	香港以西海域 Seas west of Hong Kong,	1		
	香港水域 Hong Kong Waters	3		
牛鰍 *Platycephalus indicus* (Bartail flathead)	大亞灣 Daya Bay,	1		
	香港以西海域 Seas west of Hong Kong,	1		
	香港水域 Hong Kong Waters	3		
牙帶 *Trichiurus haumela* (Hair tail)	大亞灣 Daya Bay,	1		
	香港以西海域 Seas west of Hong Kong,	1		
	香港水域 Hong Kong Waters	3		
三點蟹 *Portunus sanguinolentus* (Three-spotted crab)	香港以西海域 Seas west of Hong Kong,	1		
	香港水域 Hong Kong Waters	4		
赤米蝦 *Metapenaeopsis barbata* (Fire prawn)	香港以西海域 Seas west of Hong Kong,	1		
	香港水域 Hong Kong Waters	4		
魷魚 *Loligo edulis* (Squid)	大亞灣 Daya Bay,	1		
	香港以西海域 Seas west of Hong Kong,	1		
	香港水域 Hong Kong Waters	3		
墨魚 *Sepia spp.* (Cuttlefish)	香港水域 Hong Kong Waters	4		
蜆 *Tapes philippinarum* (Clam)	長洲 Cheung Chau,	2		
	吐露港 Tolo Harbour	2		
青口 *Perna viridis* (Green-lipped mussel)	長洲 Cheung Chau,	3		
	吐露港 Tolo Harbour,	3		
	大亞灣 Daya Bay	3		

表1. (續)
Table 1. (cont’d)

樣本類別 **Sample type**	取樣地點 **Sampling location**	樣本數目 **Number of samples**[1]	分析類別 **Type of analysis**	取樣頻率 **Sampling frequency**
水體樣本 Aquatic Samples				
東風螺 *Babylonia formosae* (Gastropod)	香港水域 Hong Kong Waters	4	伽馬 γ, 氚 H-3, 鍶-90 Sr-90, 鈈-239 Pu-239	每季 quarterly
石蓴 *Ulva lactuca* (Sea lettuce)	布袋澳 Po Toi O	2		冬季及春季 winter and spring
滸苔 *Enteromorpha prolifera* (Sea hair)	吐露港 Tolo Harbour	1		冬季 winter
長紫菜 *Porphyra dentata* (Red algae)	香港水域 Hong Kong Waters[2]	1		
半葉馬尾藻 *Sargassum hemiphyllum* (Brown algae)	布袋澳 Po Toi O	2		冬季及春季 winter and spring
潮間帶土(上層及下層) Intertidal sediment (upper and lower level)	白沙灣 Pak Sha Wan,	8	伽馬 γ, 鈈-239 Pu-239	每季 quarterly
	尖鼻咀 Tsim Bei Tsui,	8		
	沙頭角 Sha Tau Kok	8		
海床沉澱物 Seabed sediment	大灘海 Tai Tan Hoi,	1	伽馬 γ, 鈈-239 Pu-239	每年 yearly
	龍蝦灣 Lung Ha Wan,	1		
	索罟灣 Picnic Bay,	1		
	西區碇泊處 Western Anchorage	1		

註:

(1) 表列數是二零二零年內取樣數目。
(2) 近年已無法在蒲台島收集長紫菜樣本，天文台於二零二零年將取樣地點擴闊至香港水域內其他地點。

Note:

(1) The number listed in the table is the number of samples collected in 2020.
(2) *Porphyra dentata* (Red algae) could not be found in Po Toi Island in recent years. The Observatory extended the sampling location to other areas within Hong Kong Waters in 2020.

表 2.　二零二零年樣本之主要量度參數概要[1]
Table 2.　Summary of key measurement parameters for samples in 2020[1]

測量類別 Measurement type		空氣流量 Air Flow Rate	樣本大小 Sample size	計數時間(秒) Counting time (second)	探測下限[2] Minimum Detectable Activity[2] (MDA)	
					碘-131 I-131	銫-137 Cs-137
伽馬放射性核素 Gamma emitting radionuclides	大氣飄塵 Airborne Particulate	17 m^3h^{-1} (由高容量取樣器收集) (collected by High Volume Air Sampler)	12000 m^3 (累積每月樣本 bulked monthly sample)	55000	10 µBq m^{-3}	10 µBq m^{-3}
			3000 m^3 (每週樣本 weekly sample)	20000	50 µBq m^{-3}	50 µBq m^{-3}
		800 m^3h^{-1} (由更高容量採樣器收集)[3] (collected by Enhanced High Volume Air Sampler)[3]	800 m^3 (每小時樣本 hourly sample) – 19200 m^3 (每日樣本 daily sample)	900 – 10800	60 – 8000 µBq m^{-3}	60 – 10000 µBq m^{-3}
	氣態碘 Gaseous Iodine	2.5 m^3h^{-1} (由放射性碘取樣器收集) (collected by Radioiodine Sampler)	400 m^3 (每週樣本 weekly sample)	55000	300 µBq m^{-3}	-
		7 m^3h^{-1} (由更高容量採樣器收集)[3] (collected by Enhanced High Volume Air Sampler)[3]	7 m^3 (每小時樣本 hourly sample) – 168 m^3 (每日樣本 daily sample)	900 – 10800	2 – 150 mBq m^{-3}	-
	濕沉積物 Wet deposition	-	4 L	55000	0.2 Bq L^{-1}	0.2 Bq L^{-1}
	總沉積物 Total deposition	-	0.03 m^2	55000	15 Bq m^{-2}	15 Bq m^{-2}
	食米 Rice	-	4 kg	20000	0.1 Bq kg^{-1}	0.1 Bq kg^{-1}
	牛奶 Milk	-	1 L	55000	0.2 Bq L^{-1}	0.3 Bq L^{-1}
	蔬菜 Vegetable	-	1 kg	20000	0.3 Bq kg^{-1}	0.4 Bq kg^{-1}
	水果 Fruit	-	2 kg	20000	0.3 Bq kg^{-1}	0.3 Bq kg^{-1}
	家禽 Poultry	-	2 kg	20000	0.2 Bq kg^{-1}	0.2 Bq kg^{-1}
	肉類 Meat	-	1 kg	20000	0.4 Bq kg^{-1}	0.4 Bq kg^{-1}
	土壤 Land soil	-	1 kg	20000	1.0 Bq kg^{-1}	1.5 Bq kg^{-1}
	水樣本 Water samples	-	4 L	55000	0.1 Bq L^{-1}	0.1 Bq L^{-1}
	海水中懸浮粒子 Suspended particulate	-	5 L	55000	0.02 Bq L^{-1}	0.02 Bq L^{-1}
	海產 Seafood	-	2 kg	72000	0.1 Bq kg^{-1}	0.1 Bq kg^{-1}
	海藻 Seaweed	-	0.5 kg	20000	1 Bq kg^{-1}	2 Bq kg^{-1}
	潮間帶土/海床沉澱物 Intertidal/seabed sediment	-	2 kg	20000	0.5 Bq kg^{-1}	0.5 Bq kg^{-1}

表 2. (續)
Table 2. (cont'd)

測量類別 Measurement type		樣本大小 Sample size	計數時間(秒) Counting time (second)	本底 Background (CPM)	計數效率 Counting efficiency (%)	化學復得率 Chemical recovery (%)	探測下限[2] Minimum Detectable Activity[2] (MDA)
氚 Tritium	濕沉積物 Wet deposition	0.007 L	18000	2	25	-	4 Bq L^{-1}
	總沉積物 Total deposition	0.0001 m^2					300 Bq m^{-2}
	水蒸氣 Water vapour	2 m^3					0.01 Bq m^{-3}
	食米 Rice	0.08 kg					0.3 Bq kg^{-1}
	牛奶 Milk	0.007 L					4 Bq L^{-1}
	蔬菜 Vegetable	0.008 kg					3 Bq kg^{-1}
	水果 Fruit	0.01 kg					3 Bq kg^{-1}
	家禽 Poultry	0.02 kg					2 Bq kg^{-1}
	肉類 Meat	0.01 kg					3 Bq kg^{-1}
	水樣本 Water samples	0.007 L					4 Bq L^{-1}
	地下水 Underground water	0.1 L					0.3 Bq L^{-1}
	海產 Seafood	0.02 kg					1 Bq kg^{-1}
	海藻 Seaweed	0.05 kg					1 Bq kg^{-1}
鍶-90 Strontium-90	大氣飄塵 Airborne particulate	5000 m^3	30000	1	75	90	1 μ Bq m^{-3}
	濕沉積物 Wet deposition	2 L				100	0.002 Bq L^{-1}
	總沉積物 Total deposition	0.01 m^2					0.5 Bq m^{-2}
	米 Rice	3 kg				90	0.002 Bq kg^{-1}
	牛奶 Milk	1 L					0.005 Bq L^{-1}
	蔬菜 Vegetable	1 kg					0.005 Bq kg^{-1}
	水果 Fruit	2 kg					0.003 Bq kg^{-1}
	家禽 Poultry						0.003 Bq kg^{-1}
	肉類 Meat	1 kg					0.005 Bq kg^{-1}
	土壤 Land soil	0.005 kg					1 Bq kg^{-1}
	海水中懸浮粒子 Suspended particulate	3 L					0.002 Bq L^{-1}
	海產 Seafood	1.5 kg					0.004 Bq kg^{-1}
	海藻 Seaweed	0.05 kg					0.1 Bq kg^{-1}

表 2. (續)
Table 2. (cont’d)

測量類別 Measurement type		樣本大小 Sample size	計數時間(秒) Counting time (second)	本底 Background (CPM)	計數效率 Counting efficiency (%)	化學復得率 Chemical recovery (%)	探測下限[2] Minimum Detectable Activity[2] (MDA)
鈈-239 Plutonium-239	大氣飄塵 Airborne particulate	6000 m^3	220000	0.003	20	40	0.2 μ Bq m^{-3}
	濕沉積物 Wet deposition	2 L				60	0.0004 Bq L^{-1}
	總沉積物 Total deposition	0.01 m^2					0.07 Bq m^{-2}
	土壤 Land soil	0.003 kg				50	0.3 Bq kg^{-1}
	海水中懸浮粒子 Suspended particulate	3 L					0.0003 Bq L^{-1}
	海產 Seafood	0.5 kg				40	0.002 Bq kg^{-1}
	海藻 Seaweed	0.05 kg				60	0.01 Bq kg^{-1}
	潮間帶土 / 海床沉澱物 Intertidal/ seabed sediment	0.003 kg				50	0.3 Bq kg^{-1}

註:

(1) 表內所列是 ERMP 在二零二零年主要量度參數的典型數值，僅供參考之用。視乎實際操作情況，量度參數可能有變化。在特別情況下，部份樣本會使用與上表頗為不同的參數進行量度。

(2) 測量的探測下限是指一個測量系統在該次測量時實際能測量到的最低活度水平。探測下限的數值取決於多個因數，包括個別測量系統的特質、測量方法、樣本的特質及測量的情況，所以探測下限會隨著個別樣本和測量而改變。表內所示的探測下限為在一般測量情況下的典型數值，僅供在理解此報告的結果時作簡易參考之用。有時在個別樣本的測量情況下，可能測量出遠低於探測下限的活度水平。

(3) 列出的數值為更高容量採樣器使用的參數和探測下限的一般範圍。採樣及計數時間或會按不同情況而改變。

Note:

(1) The values given in the table are typical values of key measurement parameters in the ERMP in 2020. The values may vary in practice, and should thus be used as reference only. Under special circumstances, some samples may be measured under substantially different conditions.

(2) The minimum detectable activity (MDA) of a measurement is the lowest activity level that is practically achievable by the counting system for that measurement. MDA values depend on various factors, including the characteristics of the measurement system, method of measurement, sample characteristics and measurement conditions, and thus vary with individual samples and measurements. The listed MDAs are typical values under ordinary measurement conditions and serve as a quick reference in interpreting results in this report. Under individual measurement conditions, activity much lower than the typical MDA would sometimes be measured.

(3) The values listed are the typical ranges of parameters and MDA of the Enhanced High Volume Air Sampler (EHVAS). The sampling and counting times will be adjusted depending on different situations.

表 3a. 輻射監測網絡在二零二零年錄得的環境伽馬劑量率
(單位為每小時微戈)

Table 3a. Ambient gamma dose rates recorded by the radiation monitoring network in 2020 (dose rate in μGy h^{-1})

輻射監測站 **Radiation Monitoring Station**	**年平均值** **Annual Average**	**標準差** **Standard Deviation**	**一分鐘平均值變幅** **Variation of 1-min Average**
吉澳 Kat O	0.106	0.003	0.087 – 0.183
京士柏 King’s Park	0.141	0.003	0.128 – 0.281
觀塘 Kwun Tong	0.123	0.002	0.102 – 0.189
平洲 Ping Chau	0.090	0.004	0.071 – 0.192
西灣河 Sai Wan Ho	0.093	0.002	0.084 – 0.152
沙頭角 Sha Tau Kok	0.101	0.002	0.091 – 0.149
大美督 Tai Mei Tuk(2)	0.113	0.003	0.098 – 0.167
塔門 Tap Mun	0.086	0.002	0.066 – 0.150
尖鼻咀 Tsim Bei Tsui	0.130	0.002	0.118 – 0.199
元五墳 Yuen Ng Fan	0.121	0.003	0.108 – 0.200
赤鱲角 Chek Lap Kok	0.147	0.004	0.132 – 0.212
鶴咀 Cape D’Aguilar	0.129	0.004	0.114 – 0.212
参考範圍(1) **Reference Range**(1)			0.062 – 0.271

註: (1) 参考範圍為一九九二至一九九六年輻射監測網絡錄得的環境伽馬劑量率範圍。
(2) 大美督監測站於二零二零年五月八日更換高壓電離室，更新儀器後錄得的數據跟之前大致相若。

Note: (1) Reference range is the ambient gamma dose rates recorded by the radiation monitoring network from 1992 to 1996.
(2) The high pressure ionization chambers in the radiation monitoring station at Tai Mei Tuk was replaced on 8 May 2020. The gamma dose rates measured before and after equipment replacement were generally similar.

表 3b. 熱釋光劑量計網絡在二零二零年錄得的環境伽馬劑量率
(單位為每小時微戈)

Table 3b. Ambient gamma dose rates recorded by the thermoluminescent dosimeter network in 2020 (dose rate in μGy h^{-1})

熱釋光劑量計監測點 TLD Location	**年平均值 Annual Average**	**標準差 Standard Deviation**	**變幅 Variation**
鶴咀 Cape D'Aguilar	0.14	0.01	0.12 – 0.16
赤鱲角 Chek Lap Kok	0.15	0.02	0.12 – 0.16
長洲 Cheung Chau	0.11	0.02	0.09 – 0.13
置富花園 Chi Fu Fa Yuen	0.14	0.01	0.13 – 0.15
清水灣 Clear Water Bay	0.14	0.02	0.12 – 0.16
深水灣 Deep Water Bay	0.11	0.01	0.10 – 0.11
粉嶺 Fanling	0.12	0.01	0.11 – 0.12
跑馬地 Happy Valley(2)	0.09	0.01	0.08 – 0.10
吉澳 Kat O	0.11	0.01	0.09 – 0.12
京士柏 King's Park	0.14	0.01	0.13 – 0.16
觀塘 Kwun Tong	0.11	0.01	0.10 – 0.13
平洲 Ping Chau	0.12	0.02	0.11 – 0.14
西貢 Sai Kung	0.10	0.01	0.09 – 0.11
沙頭角 Sha Tau Kok	0.09	0.01	0.08 – 0.10
BRMP 參考數值(1) BRMP Reference Values(1)			0.03 – 0.29

表 3b. (續)

Table 3b. (cont'd)

熱釋光劑量計監測點 **TLD Location**	年平均值 **Annual Average**	標準差 **Standard Deviation**	變幅 **Variation**
沙田 Sha Tin	0.13	0.01	0.13 – 0.15
筲箕灣 Shau Kei Wan	0.13	0.02	0.12 – 0.16
石崗 Shek Kong(3)	0.12	0.01	0.11 – 0.12
石梨貝 Shek Lei Pui	0.19	0.02	0.16 – 0.21
大欖涌 Tai Lam Chung	0.17	0.03	0.14 – 0.20
大美督 Tai Mei Tuk	0.14	0.01	0.13 – 0.15
大埔 Tai Po	0.10	0.01	0.09 – 0.11
塔門 Tap Mun	0.09	0.01	0.09 – 0.10
尖鼻咀 Tsim Bei Tsui	0.13	0.01	0.11 – 0.14
青衣 Tsing Yi	0.12	0.01	0.12 – 0.13
荃灣 Tsuen Wan	0.14	0.02	0.12 – 0.18
屯門 Tuen Mun	0.13	0.01	0.11 – 0.15
烏溪沙 Wu Kai Sha	0.14	0.02	0.12 – 0.16
元朗 Yuen Long	0.11	0.03	0.09 – 0.15
元五墳 Yuen Ng Fan	0.12	0.01	0.11 – 0.14
BRMP 參考數值(1) **BRMP Reference Values**(1)			0.03 – 0.29

註: (1) BRMP 參考數值為熱釋光劑量計網絡於 BRMP 期間所錄得的環境伽馬劑量率範圍。

(2) 位於跑馬地的熱釋光劑量計於第二季更換時出現問題，該站的第二季數據沒有被納入計算。

(3) 受 2019 冠狀病毒疫情影響，石崗場地設有進出管制，天文台未能按時更換該站第三季的熱釋光劑量計，因此該組劑量計記錄了一段較長時間的數據，涵蓋了第三及第四季。

Note: (1) BRMP reference values represent the range of the ambient gamma dose rates recorded by the thermoluminescent dosimeter network during BRMP.

(2) Problems occurred with the TLDs in Happy Valley during their replacement in the second quarter. The data for the second quarter of that site were not included in the calculation.

(3) Owing to the COVID-19 pandemic, access restriction was implemented by site owner in Shek Kong. The Observatory could not replace the TLDs of that site in the third quarter as scheduled. As a result, data recorded in those TLDs spanned over a relatively long period of time, covering the third and fourth quarters.

表 4. 平洲自動伽馬譜法系統在二零二零年的輻射測量結果

Table 4. Results of measurement by the Automatic Gamma Spectrometry System at Ping Chau in 2020

	空氣流量(1) **Air Flow Rate**(1)	**年平均值 Annual Average**	**標準差 Standard Deviation**	**日平均值範圍 Range of Daily Average**	**首五年運作 (一九九七至二零零一年) 參考範圍(2) Reference range from first 5 years of operation (1997 - 2001)** (2)
阿爾法粒子 Alpha (每立方米貝可 Bq m^{-3})	15 & 30 m^3h^{-1}	1.5	0.5	1.0 – 3.3	1.0 – 5.8
貝他粒子 Beta (每立方米貝可 Bq m^{-3})	15 & 30 m^3h^{-1}	2.1	1.2	1.0 – 7.4	1.0 – 10.1
碘-131 I-131 (每立方米毫貝可 mBq m^{-3})	15 & 30 m^3h^{-1}	< 4	N/A(3)	N/A	< 4(4)
銫-137 Cs-137 (每立方米毫貝可 mBq m^{-3})	15 & 30 m^3h^{-1}	< 4	N/A	N/A	< 4
氣態碘-131 Gaseous I-131 (每立方米貝可 Bq m^{-3})	4 m^3h^{-1}	< 1	N/A	N/A	< 1

註: (1) 因硬件設計改變，新舊系統收集大氣飄塵的空氣流量有所不同，新系統及舊系統的典型空氣流量分別為每小時15及30立方米。

(2) 自動伽馬譜法系統的主要目的是測量人工放射性核素。一般情況下，其阿爾法粒子和貝他粒子數值顯示該系統在環境中所錄得的變化，而並非環境中阿爾法及貝他粒子的含量。

(3) N/A 表示不適用。

(4) 測量結果低於探測下限以 “< xx” 表示，xx是該類測量的典型探測下限值。

Note: (1) Due to change in hardware design, the flow rates of the new and old systems for collecting airborne particulates are different. The typical flow rates of the new and old systems are 15 and 30 m^3h^{-1} respectively.

(2) Automatic Gamma Spectrometry System aims at detecting artificial radionuclides. In general, the alpha and beta values obtained by the system indicate the variations as depicted by the system in the environment, rather than the concentration of alpha and beta activities in the environment.

(3) N/A means ‘Not applicable’.

(4) Results below the minimum detectable activity (MDA) are reported as “< xx” where xx is the typical MDA value for that type of measurement.

表 5. 二零二零年宇宙輻射引致的伽馬劑量率測量結果 (測量地點: 船灣淡水湖)

Table 5. Measurement results of gamma dose rates due to cosmic radiation in 2020 (measurement site: Plover Cove)

測量日期 Date of measurement	**平均伽馬劑量率(每小時微戈) Average gamma dose rate (μGy h^{-1})**
二零二零年三月九日 9 Mar 2020	0.033
二零二零年五月十三日 13 May 2020	0.032
二零二零年八月十四日 14 Aug 2020	0.032
二零二零年十一月二十五日 25 Nov 2020	0.035

表 6. 二零二零年食物及環境樣本中之人工伽馬放射性核素的可測量[(1)]伽馬活度測量結果

Table 6. Measurement results of measurable[(1)] gamma activities of artificial gamma-emitting radionuclides in food and environmental samples in 2020

(每公斤貝可 Bq kg^{-1})

放射性核素: 銫-137 Radionuclide: Cs-137

類別 Type	地點 Location	含有可測量活度的樣本總數 Total no. of samples with measurable activity	範圍 Range	活度[(2)] Activity[(2)]	BRMP 範圍[(3)] BRMP range[(3)]	單位 Unit
牙帶 *Trichiurus haumela* (Hair tail)	大亞灣 Daya Bay	1	-	0.1	≤ 0.2	Bq kg^{-1}
	香港以西海域 Seas west of Hong Kong	1	-	0.1		
土壤(上層) Land soil (upper)	見表 1 See Table 1	4	0.7 – 2.3	1.5	≤ 10.0	Bq kg^{-1}
土壤(下層) Land soil (lower)	見表 1 See Table 1	5	0.4 – 1.8	1.0	≤ 4.0	Bq kg^{-1}
潮間帶土(上層) Intertidal sediment (upper)	白沙灣 Pak Sha Wan	4	0.3 – 0.4	0.4	≤ 2.4	Bq kg^{-1}
	尖鼻咀 Tsim Bei Tsui	4	0.4 – 0.6	0.5		
	沙頭角 Sha Tau Kok	4	0.6 – 0.8	0.7		
潮間帶土(下層) Intertidal sediment (lower)	白沙灣 Pak Sha Wan	3	0.3 – 0.3	0.3	≤ 3.1	Bq kg^{-1}
	尖鼻咀 Tsim Bei Tsui	3	0.5 – 0.7	0.6		
	沙頭角 Sha Tau Kok	4	0.4 – 0.6	0.5		
海床沉澱物 Seabed sediment	大灘海 Tai Tan Hoi	1	-	0.4	≤ 1.9	Bq kg^{-1}
	龍蝦灣 Lung Ha Wan	1	-	0.6		
	索罟灣 Picnic Bay	1	-	0.4		

註: (1) 當在樣本中可分辨出相關核素的伽馬射線能峰，而測量信號亦高於該能譜本底時，該樣本的測量結果視為“可測量”。
(2) 如有多過一個樣本發現可測量活度，此欄則報告平均值。
(3) BRMP 測量結果低於探測下限以 “< xx” 表示，xx 是該類測量的典型探測下限值。如只在部份樣本中探測到該放射性核素，結果將報告為 “≤ xx” ，xx 則為測量到的活度最大值。

Note: (1) When the gamma energy peak(s) of the concerned nuclide is/are discernible in a sample and the detected signal is above the respective spectral background, the measurement result of that sample is considered as “measurable”.
(2) The mean activity is reported if there are more than one sample with measurable activities.
(3) BRMP results that are below the minimum detectable activity (MDA) are reported as “< xx” where xx is the typical MDA value for that type of measurement. When a particular radionuclide was detected only in some of the samples in a certain sample type, the results will be reported as “≤ xx” where xx is the maximum measured activity value.

表 7. 二零二零年食物及環境樣本的可測量(1)氚活度測量結果

Table 7. Measurement results of measurable(1) activities of tritium in food and environmental samples in 2020

(每公斤貝可 Bq kg^{-1}；每公升貝可 Bq L^{-1}；每平方米貝可 Bq m^{-2}；每立方米貝可 Bq m^{-3})

類別 Type	地點 Location	含有可測量活度的樣本總數 Total no. of samples with measurable activity	範圍 Range	活度(2) Activity(2)	BRMP 範圍(3) BRMP range(3)	單位 Unit
食米 Rice	內地(珠江三角洲) Mainland (Pearl River Delta)	2	0.1 – 0.1	0.1	< 1	Bq kg^{-1}
牛奶(經消毒) Pasteurized milk	內地(深圳) Mainland (Shenzhen)	1	-	0.6	< 6	Bq L^{-1}
	內地(惠州) Mainland (Huizhou)	1	-	0.9		
菜心 Choi sum	內地(深圳) Mainland (Shenzhen)	1	-	0.8	≤ 7.4	Bq kg^{-1}
	本地 Local	1	-	0.9		
白菜 Pak choi	內地(深圳) Mainland (Shenzhen)	1	-	1.8	< 6	Bq kg^{-1}
	本地 Local	1	-	2.9		
香蕉 Banana	內地(廣東) Mainland (Guangdong)	1	-	1.8	< 3	Bq kg^{-1}
荔枝 Lychee	內地(廣東) Mainland (Guangdong)	1	-	0.7	< 4	Bq kg^{-1}
雞 Chicken	內地(廣東) Mainland (Guangdong)	2	0.3 – 0.5	0.4	≤ 2.2	Bq kg^{-1}
	本地 Local	3	0.1 – 0.7	0.4		
鴨 Duck	內地(廣東) Mainland (Guangdong)	2	0.2 – 0.7	0.4	≤ 3.5	Bq kg^{-1}
牛肉 Beef	內地(廣東) Mainland (Guangdong)	2	1.6 – 2.8	2.2	≤ 5.3	Bq kg^{-1}
豬肝 Pig's liver	內地(廣東) Mainland (Guangdong)	2	0.8 – 0.9	0.8	< 4	Bq kg^{-1}
	本地 Local	2	0.4 – 1.5	1.0		
豬肉 Pork	內地(廣東) Mainland (Guangdong)	3	0.8 – 2.1	1.3	< 4	Bq kg^{-1}
	本地 Local	2	1.0 – 1.4	1.2		
大魚 *Aristichthys nobilis* (Big-head carp)	內地(深圳) Mainland (Shenzhen)	1	-	0.4	< 2	Bq kg^{-1}

表 7. (續)

Table 7. (cont'd)

類別 Type	**地點 Location**	**含有可測量活度的樣本總數 Total no. of samples with measurable activity**	**範圍 Range**	**活度[(2)] Activity[(2)]**	**BRMP 範圍[(3)] BRMP range[(3)]**	**單位 Unit**
瓜三 *Nemipterus japonicus* (Melon coat)	香港水域 Hong Kong Waters	2	0.1 – 1.1	0.6	< 2	Bq kg^{-1}
牛鰍 *Platycephalus indicus* (Bartail flathead)	香港水域 Hong Kong Waters	2	0.2 – 0.9	0.6	< 2	Bq kg^{-1}
三點蟹 *Portunus sanguinolentus* (Three-spotted crab)	香港水域 Hong Kong Waters	2	0.3 – 0.4	0.4	< 2	Bq kg-1
赤米蝦 *Metapenaeopsis barbata* (Fire prawn)	香港水域 Hong Kong Waters	1	-	0.4	≤ 4.9	Bq kg^{-1}
墨魚 *Sepia spp.* (Cuttlefish)	香港水域 Hong Kong Waters	1	-	0.1	≤ 2.7 [(4)]	Bq kg^{-1}
魷魚 *Loligo edulis* (Squid)	香港水域 Hong Kong Waters	2	0.1 – 1.7	0.9	< 3	Bq kg^{-1}
東風螺 *Babylonia formosae* (Gastropod)	香港水域 Hong Kong Waters	2	0.1 – 0.2	0.1	< 1	Bq kg^{-1}
蜆 *Tapes philippinarum* (Clam)	長洲 Cheung Chau	1	-	0.5	< 2	Bq kg^{-1}
	吐露港 Tolo Harbour	1	-	0.2		
半葉馬尾藻 *Sargassum hemiphyllum* (Brown algae)	布袋澳 Po Toi O	1	-	0.5	< 2	Bq kg^{-1}
石蒓 Ulva lactuca (Sea lettuce)	布袋澳 Po Toi O	1	-	0.8	< 2	Bq kg^{-1}

表 7. (續)

Table 7. (cont’d)

類別 Type	地點 Location	含有可測量活度的樣本總數 Total no. of samples with measurable activity	範圍 Range	活度[2] Activity[2]	BRMP 範圍[3] BRMP range[3]	單位 Unit
濕沉積物 (降雨) Wet deposition (precipitation)	京士柏 King’s Park	1	-	0.3	≤ 12	Bq L^{-1}
	沙頭角 Sha Tau Kok	2	0.3 – 0.4	0.3		
	元五墳 Yuen Ng Fan	2	0.2 – 1.4	0.8		
總沉積物 Total deposition	京士柏 King’s Park	3	66 – 559	274	≤ 2210 [5]	Bq m^{-2}
大氣水蒸氣 Water vapour in air	京士柏 King’s Park	5	0.01 - 0.01	0.01	≤ 242 [6]	Bq m-3
飲用水(經處理) Drinking water (treated)	九龍配水管 Kowloon distribution tap	2	0.1– 0.6	0.4	< 6	Bq L^{-1}
	油柑頭濾水廠 Yau Kom TauWater Treatment Works	1	-	0.7		
	屯門濾水廠 Tuen Mun Water Treatment Works	1	-	0.7		
	沙田濾水廠 Sha Tin Water Treatment Works	1	-	2.4		
飲用水 (未經處理) Drinking water (untreated)	油柑頭濾水廠 Yau Kom Tau Water Treatment Works	1	-	0.8	< 6	Bq L^{-1}
	屯門濾水廠 Tuen Mun Water Treatment Works	2	0.1 – 0.7	0.4		
	沙田濾水廠 Sha Tin Water Treatment Works	1	-	1.2		
	萬宜水庫 High Island Reservoir	2	1.3 – 1.9	1.6		
	船灣淡水湖 Plover Cove Reservoir	2	0.1 – 1.0	0.5		

表 7. (續)

Table 7. (cont'd)

類別 Type	地點 Location	含有可測量活度的樣本總數 Total no. of samples with measurable activity	範圍 Range	活度(2) Activity(2)	BRMP 範圍(3) BRMP range(3)	單位 Unit
地下水 Underground water	環翠邨 Wan Tsui Estate	1	-	0.1	≤ 2.8	Bq L^{-1}
海水(上層) Sea water (upper level)	橫瀾島 Waglan Island	2	0.6 – 4.5	2.6	< 6	Bq L^{-1}
海水(中層) Sea water (middle level)	火石洲 Basalt Island	1	-	0.1	< 6	Bq L^{-1}
	大浪灣 Tai Long Wan	1	-	0.7		
	橫瀾島 Waglan Island	2	0.5 – 1.8	1.1		
海水(低層) Sea water (lower level)	大浪灣 Tai Long Wan	1	-	1.2	< 6	Bq L^{-1}
樽裝水(蒸餾水) Bottled water (Distilled)	本地 Local	2	1.5 – 2.3	1.9	≤ 4.9(7)	Bq L^{-1}

註: (1) 當樣本的探測信號高於空白樣本的探測信號時，該樣本的測量結果視為"可測量"。
(2) 如有多過一個樣本發現可測量活度，此欄則報告平均值。
(3) BRMP 測量結果低於探測下限以 "< xx" 表示，xx 是該類測量的典型探測下限值。如只在部份樣本中探測到該放射性核素，結果將報告為 "≤ xx" ，xx 則為測量到的活度最大值。
(4) 該樣本測量始於一九九七年十月，並沒有在 BRMP 測量。這裡顯示的測量範圍為該樣本首五年的測量數值。
(5) 該樣本測量始於一九九六年一月，並沒有在 BRMP 測量。這裡顯示的測量範圍為該樣本首五年的測量數值。
(6) 現時測量的準確度相比 BRMP 時大幅提高，同時探測下限亦大幅下降，原因是在 2008 年應用了新的液體閃爍計數系統作測量及在 2011 年採用了新的樣本前處理方法。
(7) 該樣本測量始於二零零七年五月，並沒有在 BRMP 測量。這裡顯示的測量範圍為該樣本首五年的測量數值。

Note: (1) When the detected signal of a sample is stronger than that of a blank sample, the measurement result of that sample is considered as "measurable".
(2) The mean activity is reported if there is more than one sample with measurable activities.
(3) BRMP results that are below the minimum detectable activity (MDA) are reported as "< xx" where xx is the typical MDA value for that type of measurement. When a particular radionuclide was detected only in some of the samples in a certain sample type, the results will be reported as "≤ xx" where xx is the maximum measured activity value.
(4) Measurement of this sample started in October 1997. The sample was not measured in BRMP. The indicated range refers to results from first 5 years' sample measurement.
(5) Measurement of this sample started in January 1996. The sample was not measured in BRMP. The indicated range refers to results from first 5 years' sample measurement.
(6) Substantially higher accuracy and lower detection limit are achieved for current measurement when compared to those of the BRMP owing to the implementation of a new Liquid Scintillation Counting System for measurement in 2008 and the adoption of a new sample pre-treatment method in 2011.
(7) Measurement of this sample started in May 2007. The sample was not measured in BRMP. The indicated range refers to results from first 5 years' sample measurement.

表 8. 二零二零年食物及環境樣本的可測量(1)鍶-90 活度測量結果

Table 8. Measurement results of measurable(1) activities of strontium-90 in food and environmental samples in 2020

(每公斤貝可 Bq kg^{-1}；每公升貝可 Bq L^{-1}；每立方米貝可 Bq m^{-3}；每平方米貝可 Bq m^{-2}；每公斤毫貝可 mBq kg^{-1}；每公升毫貝可 mBq L^{-1}；每立方米微貝可μBq m^{-3})

類別 Type	**地點 Location**	**含有可測量活度的樣本總數 Total no. of samples with measurable activity**	**範圍 Range**	**活度(2) Activity(2)**	**BRMP 範圍(3) BRMP range(3)**	**單位 Unit**
菜心 Choi sum	內地(深圳) Mainland (Shenzhen)	3	17 – 28	24	≤ 266	mBq kg^{-1}
	本地 Local	3	6 – 39	21		
白菜 Pak choi	內地(深圳) Mainland (Shenzhen)	2	7 – 7	7	≤ 570	mBq kg^{-1}
	本地 Local	3	12 – 15	14		
柑橘 Mandarin	內地(廣東) Mainland (Guangdong)	1	-	2	≤ 84	mBq kg^{-1}
牛肉 Beef	內地(廣東) Mainland (Guangdong)	1	-	7	≤ 35	mBq kg^{-1}
豬肝 Pig’s liver	內地(廣東) Mainland (Guangdong)	2	9 – 38	23	≤ 43	mBq kg^{-1}
大魚 *Aristichthys nobilis* (Big-head carp)	元朗 Yuen Long	1	-	4	≤ 94	mBq kg^{-1}
瓜三 *Nemipterus japonicus* (Melon coat)	香港水域 Hong Kong Waters	2	6 – 6	6	≤ 21	mBq kg^{-1}
牛鰍 *Platycephalus indicus* (Bartail flathead)	大亞灣 Daya Bay	1	-	3	≤ 21	mBq kg^{-1}
三點蟹 *Portunus sanguinolentus* (Three-spotted crab)	香港水域 Hong Kong Waters	1	-	11	≤ 105	mBq kg^{-1}
	香港以西海域 Seas west of Hong Kong	1	-	6		

表 8. (續)

Table 8. (cont'd)

類別 Type	地點 Location	含有可測量活度的樣本總數 Total no. of samples with measurable activity	範圍 Range	活度(2) Activity(2)	BRMP 範圍(3) BRMP range(3)	單位 Unit
赤米蝦 *Metapenaeopsis barbata* (Fire prawn)	香港水域 Hong Kong Waters	2	7 – 10	8	≤ 66	mBq kg^{-1}
東風螺 *Babylonia formosae* (Gastropod)	香港水域 Hong Kong Waters	1	-	5	≤ 31	mBq kg^{-1}
青口 *Perna viridis* (Green-lipped mussel)	長洲 Cheung Chau	2	22 – 22	22	≤ 47	mBq kg^{-1}
	吐露港 Tolo Harbour	3	9 – 36	21		
	大亞灣 Daya Bay	3	11 – 24	16		
蜆 *Tapes philippinarum* (Clam)	長洲 Cheung Chau	2	19 – 20	19	≤ 32	mBq kg^{-1}
	吐露港 Tolo Harbour	1	-	15		
石蓴 *Ulva lactuca* (Sea lettuce)	布袋澳 Po Toi O	1	-	132	≤ 200	mBq kg^{-1}
半葉馬尾藻 *Sargassum hemiphyllum* (Brown algae)	布袋澳 Po Toi O	2	242 – 675	459	≤ 1440	mBq kg^{-1}
大氣飄塵 Airborne particulate	京士柏 King's Park	1	-	3.4	≤ 5	µBq m^{-3}
	元五墳 Yuen Ng Fan	2	3.4 – 4.7	4.0		
總沉積物 Total deposition	京士柏 King's Park	2	1.4 – 3.6	2.5	≤ 3.9 (4)	Bqm^{-2}
濕沉積物(降雨) Wet deposition (precipitation)	京士柏 King's Park	2	20.5 – 36.1	28.3	≤ 39	mBq L^{-1}
	沙頭角 Sha Tau Kok	2	16.0 – 23.1	19.5		
	元五墳 Yuen Ng Fan	1	-	9.7		

表 8. (續)

Table 8. (cont'd)

類別 Type	地點 Location	含有可測量活度的樣本總數 Total no. of samples with measurable activity	範圍 Range	活度(2) Activity(2)	BRMP 範圍(3) BRMP range(3)	單位 Unit
土壤(上層) Land soil (upper)	見表 1. Please see Table 1.	5	0.8 – 3.4	2.2	≤ 27.3	Bq kg^{-1}
土壤(下層) Land soil (lower)	見表 1. Please see Table 1.	4	1.6 – 6.1	3.2	≤ 19.9	Bq kg^{-1}
海水中懸浮粒子(下層) Suspended particulate in sea water (lower level)	赤洲 Port Island	1	-	6.5	< 7	mBq L^{-1}
	火石洲 Basalt Island	1	-	6.8		

註: (1) 當樣本的探測信號高於本底信號時，該樣本的測量結果視為"可測量"。
(2) 如有多過一個樣本發現可測量活度，此欄則報告平均值。
(3) BRMP 測量結果低於探測下限以 "< xx" 表示，xx 是該類測量的典型探測下限值。如只在部份樣本中探測到該放射性核素，結果將報告為 "≤ xx" ，xx 則為測量到的活度最大值。
(4) 該樣本沒有在 BRMP 測量。這裡顯示的測量範圍為該樣本首五年(一九九六年至二零零零年)的測量數值。

Note: (1) When the detected signal of a sample is stronger than background signal, the measurement result of that sample is considered as "measurable".
(2) The mean activity is reported if there is more than one sample with measurable activities.
(3) BRMP results that are below the minimum detectable activity (MDA) are reported as "< xx" where xx is the typical MDA value for that type of measurement. When a particular radionuclide was detected only in some of the samples in a certain sample type, the results will be reported as "≤ xx" where xx is the maximum measured activity value.
(4) The sample was not measured in BRMP. The indicated range refers to results from first 5 years' measurement (1996 to 2000).

表 9. 二零二零年食物及環境樣本的可測量[(1)]鈈-239 活度測量結果

Table 9. Measurement results of measurable[(1)] activities of plutonium-239 in food and environmental samples in 2020

(每公斤貝可 Bq kg^{-1})

類別 Type	地點 Location	含有可測量活度的樣本總數 Total no. of samples with measurable activity	範圍 Range	活度[(2)] Activity[(2)]	BRMP 範圍[(3)] BRMP range[(3)]	單位 Unit
潮間帶土(上層) Intertidal sediment (upper)	沙頭角 Sha Tau Kok	1	-	0.18	≤ 0.19	Bq kg^{-1}
潮間帶土(下層) Intertidal sediment (lower)	尖鼻咀 Tsim Bei Tsui	1	-	0.12	≤ 0.14	Bq kg^{-1}
海床沉澱物 Seabed sediment	索罟灣 Picnic Bay	1	-	0.42	≤ 0.57	Bq kg^{-1}
	西區碇泊處 Western Anchorage	1	-	0.34		
	大灘海 Tai Tan Hoi	1	-	0.35		

註: (1) 當在樣本中可分辨出鈈-239 的阿爾法粒子能峰，而測量信號亦高於該能譜本底時，該樣本的測量結果視為"可測量"。

(2) 如有多過一個樣本發現可測量活度，此欄則報告平均值。

(3) BRMP 測量結果低於探測下限以"< xx"表示，xx 是該類測量的典型探測下限值。如只在部份樣本中探測到該放射性核素，結果將報告為"≤ xx"，xx 則為測量到的活度最大值。

Note: (1) When the alpha energy peaks of plutonium-239 are discernible in a sample and the detected signal is above the respective spectral background, the measurement result of that sample is considered as "measurable".

(2) The mean activity is reported if there is more than one sample with measurable activities.

(3) BRMP results that are below the minimum detectable activity (MDA) are reported as "< xx" where xx is the typical MDA value for that type of measurement. When a particular radionuclide was detected only in some of the samples in a certain sample type, the results will be reported as "≤ xx" where xx is the maximum measured activity value.

表 10. 二零二零年樣本整體測量結果概要

Table 10. Overall summary of measurement results of samples in 2020

(每公斤貝可 Bq kg^{-1}；每公升貝可 Bq L^{-1}；每立方米微貝可 μBq m^{-3})

途徑 Pathway	樣本類別 Sample Type	測量結果(1) Measurement results(1) / 參考數值(1) Reference values(1)	碘-131 I-131	銫-137 Cs-137	銫-134 Cs-134	氚 H-3	鍶-90 Sr-90	鈈-239 Pu-239	單位 Unit
大氣 Atmospheric	大氣飄塵 (每月累積樣本) Airborne Particulate (bulked monthly sample)	範圍 Range	< 10	< 10	< 10	---(2)	3.4–4.7	< 0.2	μBq m^{-3}
		BRMP	< 10(3)	< 10	< 10		≤ 5	< 0.2	
地面 Terrestrial	食米 Rice	範圍 Range	< 0.1	< 0.1	< 0.1	0.1–0.1	< 0.002	---	Bq kg^{-1}
		BRMP	< 0.1	≤ 0.9	< 0.1	< 1	≤ 0.056		
	牛奶 Milk	範圍 Range	< 0.2	< 0.3	< 0.3	0.6–0.9	< 0.005	---	Bq L^{-1}
		BRMP	< 0.2	≤ 0.3	< 0.3	< 6	≤ 0.081		
	蔬菜 Vegetable	範圍 Range	< 0.3	< 0.4	< 0.3	0.8–2.9	0.006–0.039	---	Bq kg^{-1}
		BRMP	< 0.3	< 0.4	< 0.3	≤ 7.4	≤ 0.570		
水體 Aquatic	魚 Fish	範圍 Range	< 0.1	0.1	< 0.1	0.1–1.1	0.003–0.006	< 0.002	Bq kg^{-1}
		BRMP	< 0.1	≤ 0.2	< 0.1	< 2	≤ 0.094	< 0.002	
	經處理的飲用水 Treated Drinking Water	範圍 Range	< 0.1	< 0.1	< 0.1	0.1–2.4	---	---	Bq L^{-1}
		BRMP	< 0.1	< 0.1	< 0.1	< 6			

註:

(1) 測量結果低於探測下限以“< xx”表示，xx 是該類測量的典型探測下限值。如只在部份樣本中探測到該放射性核素，BRMP 結果將報告為“≤ xx”，xx 則為測量到的活度最大值。

(2) --- 表示沒有在 BRMP 及 ERMP 進行此項測量。

(3) 在 BRMP 期間分析的大氣飄塵樣本中，只有京士柏兩個每週樣本測量出碘-131，活度分別是 328 μBq m^{-3} 及 38 μBq m^{-3}，但經調查後相信碘-131 是來自附近伊利沙伯醫院的小量低放射性醫療廢物排放，因此並不應將這些樣本在 BRMP 期間測量出的碘-131 活度視為大氣飄塵的本底活度範圍。大氣飄塵的 BRMP 碘-131 本底範圍應為低於探測下限。

Notes:

(1) Results that are below the minimum detectable activity (MDA) are reported as “< xx” where xx is the typical MDA value for that type of measurement. When a particular radionuclide was detected only in some of the samples in a certain sample type, the BRMP results will be reported as “≤ xx” where xx is the maximum measured activity value.

(2) --- means “Measurements not included under BRMP and ERMP”.

(3) During the BRMP period, among the airborne particulate samples analysed, I-131 was detected only in two weekly samples at King’s Park (activity 328 μBqm^{-3} and 38 μBq m^{-3}), subsequent investigation suggested that a possible source of I-131 could be the release of small amount of low-level radioactive medical waste from Queen Elizabeth Hospital nearby. Hence the I-131 activities detected in these samples during BRMP should not be interpreted as baseline activity for airborne particulate. The baseline BRMP range of I-131 in airborne particulate should be below MDA.

表 11.　二零二零年國際原子能機構安排的水樣本中放射性核素測量能力測試結果

Table 11.　Results of the 2020 proficiency test organised by the International Atomic Energy Agency for the measurement of activities of radionuclides in water sample

放射性核素 **Radionuclide**	天文台測量結果 **Measurement Result of HKO (Value_HKO) (每公斤貝可 Bq/kg)**	天文台測量結果不確定度 **Measurement Uncertainty of HKO (U_HKO) (每公斤貝可 Bq/kg)**	國際原子能機構所提供之目標值 **IAEA Target Value (Value_IAEA) (每公斤貝可 Bq/kg)**	國際原子能機構所提供之目標值不確定度 **Uncertainty of IAEA Target Value (U_IAEA) (每公斤貝可 Bq/kg)**	相對偏差[1] **Relative Bias[1] ($Bias_{relative}$) (%)**	**P[2] (%)**	國際原子能機構所提供之最大相對偏差 **Maximum Acceptable Relative Bias (MARB) provided by IAEA (%)**	準確度[3] **Accuracy[3]**	精確度[4] **Precision[4]**	天文台排名[5] /參與測試單位數目 **Ranking of HKO[5] /Number of Participating Units**
銫-134 Cs-134	32.7	1.8	33.5	0.5	-2.39	5.70	20	可接受 Acceptable	可接受 Acceptable	不適用[6] N/A[6]
銫-137 Cs-137	63.5	3.3	64.4	0.9	-1.40	5.38	20	可接受 Acceptable	可接受 Acceptable	不適用[6] N/A[6]
鈉-22 Na-22	68.3	4.2	76.8	1.2	-11.07	6.34	20	可接受 Acceptable	可接受 Acceptable	不適用[6] N/A[6]
鍶-90 Sr-90	23.0	1.6	23.9	0.3	-3.77	7.07	30	可接受 Acceptable	可接受 Acceptable	不適用[6] N/A[6]

註:　(1) 相對偏差 $Bias_{relative}$ = (Value_HKO – Value_IAEA)/Value_IAEA x 100%

(2) $P=\sqrt{(U\_IAEA/Value\_IAEA)^2 + (U\_HKO/Value\_HKO)^2} \times 100\%$

(3) 若 $Bias_{relative}$ <= MARB，測量結果之準確度為「可接受」。

(4) 若 P<=MARB 及 $Bias_{relative}$ <= k*P，測量結果之精確度為「可接受」。k 為覆蓋因子，95%置信水平時 k 為 2.56。

(5) “天文台排名”是根據每一參與測試單位的相對偏差值由小至大順序排列計算出來。

(6) 主辦單位是次沒有列出所有單位的測量結果分布，因此不能計算排名。

Note:　(1) Relative Bias, $Bias_{relative}$ = (Value_HKO – Value_IAEA)/Value_IAEA x 100%

(2) $P=\sqrt{(U\_IAEA/Value\_IAEA)^2 + (U\_HKO/Value\_HKO)^2} \times 100\%$

(3) If $Bias_{relative}$ <= MARB, accuracy of the measurement is considered “Acceptable”.

(4) If P<=MARB and $Bias_{relative}$ <= k*P, precision of the measurement is considered “Acceptable”.　k is the coverage factor.　For the 95% confidence level, k is 2.56.

(5) The “Ranking of HKO” is computed by sorting the relative biases of all the participating units in ascending order.

(6) Ranking could not be computed because the distributions of measurement results of all the participating units were not listed by the host this time.

表 12. 二零二零年政府化驗所安排就檢定奶粉樣本中銫-134 及銫-137 活度之實驗室比對結果

Table 12. Results of the 2020 inter-laboratory comparison organised by the Government Laboratory on the determination of activities of caesium-134 and caesium-137 in milk powder sample

放射性核素 Radionuclide	**天文台 測量結果 Measurement Result of the HKO (每公斤貝可 Bq/kg)**	**比對單位 1 測量結果 Measurement Result of Participating Unit 1 (PU1) (每公斤貝可 Bq/kg)**	**比對單位 2 測量結果 Measurement Result of Participating Unit 2 (PU2) (每公斤貝可 Bq/kg)**	**HKO 與 PU1 結果絕對差 Absolute Difference between HKO and PU1 (Δ_m)(1) (每公斤貝可 Bq/kg) [P_1(2)]**	**HKO 與 PU2 結果絕對差 Absolute Difference between HKO and PU2 (Δ_m)(1) (每公斤貝可 Bq/kg) [P_1(2)]**	**HKO 與 PU1 結果的 組合不確定度 Combined Uncertainty of HKO and PU1 U_Δ(HKO-PU1)(3) (每公斤貝可 Bq/kg) [P_2(4)]**	**HKO 與 PU2 結果的 組合不確定度 Combined Uncertainty of HKO and PU2 U_Δ(HKO-PU2)(3) (每公斤貝可 Bq/kg) [P_2(4)]**	**比對結果 Comparison Result**
銫-134 Cs-134	數值 Value: C_{HKO} = 47.5 不確定度 Uncertainty: U_{HKO} = 4.0	數值 Value: C_{PU1} = 41.3 不確定度 Uncertainty: U_{PU1} = 3.51	數值 Value: C_{PU2} = 44.9 不確定度 Uncertainty: U_{PU2} = 2.4	6.2 [14.0%]	2.6 [5.6%]	5.3 [11.9%]	4.7 [10.2%]	無顯著分別(5) No significant difference(5)
銫-137 Cs-137	數值 Value: C_{HKO} = 201 不確定度 Uncertainty: U_{HKO} = 16	數值 Value: C_{PU1} = 193 不確定度 Uncertainty: U_{PU1} = 16.4	數值 Value: C_{PU2} = 204 不確定度 Uncertainty: U_{PU2} = 10.4	8 [4.1%]	3 [1.5%]	22.9 [11.6%]	19.1 [9.4%]	無顯著分別(5) No significant difference(5)

註:

(1) $\Delta_m = C_{實驗室A} - C_{實驗室B}$ (2) $P_1 = \Delta_m / ((C_{實驗室A} + C_{實驗室B})/2)$ (3) $U_\Delta = \sqrt{(U_{實驗室A})^2 + (U_{實驗室B})^2}$

(4) $P_2 = U_\Delta / ((C_{實驗室A} + C_{實驗室B})/2)$ (5) 如 $\Delta_m \leq 2U_\Delta$，比對兩個測量結果為「無顯著分別」。

Note:

(1) $\Delta_m = C_{Laboratory\ A} - C_{Laboratory\ B}$ (2) $P_1 = \Delta_m / ((C_{Laboratory\ A} + C_{Laboratory\ B})/2)$ (3) $U_\Delta = \sqrt{((U_{Laboratory\ A})^2 + (U_{Laboratory\ B})^2)}$

(4) $P_2 = U_\Delta / ((C_{Laboratory\ A} + C_{Laboratory\ B})/2)$ (5) If $\Delta_m \leq 2U_\Delta$, the comparison of two measurement results is considered as "No significant difference".