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計畫名稱：空氣中生物性危害物質之監測及基礎值建立

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摘要

目前台灣於空氣基礎值之研究僅重視懸浮微粒質量及化學物質等項目分析監控，關於空氣中之生物性危害物質則尚無相關文獻，故本計畫將空氣中之生物性危害物質聚焦於細菌與真菌，初步發展空氣採樣流程、樣本中之細菌與真菌分離培養鑑定方法與最佳化，最後運用次世代基因定序之全基因組(metagenomics)分析直接觀測空氣樣本中存在之菌叢與其相對比例，以建置空氣中生物性危害物質監測模式。本計畫之樣本採集儀器係應用DYCOR之XMX空氣採樣模組，收集定點之空氣懸浮微粒樣本以進行核酸純化，輔以螢光雷射動力氣粒分析系統(FLAPS)，可分辨粒徑1~10μm間之螢光懸浮微粒，即預警為可能之生物性氣粒。另由不同時間點之PCR結果，收集30-40分鐘之樣本濃度(約24,000~32,000公升之濃縮空氣)為PCR檢測之時間最佳條件。另於定量檢體之核酸純化PCR膠體電泳結果本計畫所建立之醋酸氨核酸純化法可行且優於市售之核酸萃取套組；由本實驗單一樣本檢送測次世代基因定序之結果顯示，上述單一樣本萃取之核酸總量太低仍不足進行次世代基因定序之序列庫創建(library construction)，我們需克服此窒礙，並已補送檢體重新測定中。其次本實驗結合空氣粒子計數器同時測定採集點之空氣粒子數值，建立XMX收樣體積換算空氣粒子數之推估算式，進而比較測得之螢光粒子與氣候因子，如溫度、相對濕度與風速等影響因素以瞭解其間關係，此亦為空氣背景基礎值中重要之參考數據。依據上述建立之方法，可規劃1~2年之常態性研究確認可用並完成背景資料建置，這些資訊將可應用未來生物預警系統建置。

關鍵詞： 空氣中生物性危害物質、全基因組分析、次世代基因定序、細菌、真菌、空氣採樣模組、螢光雷射動力氣粒分析系統、生物預警系統

ABSTRACT

In Taiwan, only the suspended particle mass and chemicals in the air were noticed for baseline construction currently, but the aerosol biohazards were not as yet reported. Herein, we develop air sampling procedures and culture methods to analyze the composition and distribution of bacteria and fungi in the air for identification and optimization. Moreover, the metagenomics methods of next generation sequencing would be utilized to analyze the species of aerosol flora and their relative proportions directly in the air collection, and then to establish the aerosol biohazards monitoring model. In this project, an XMX air sampling module from DYCOR company (Canada) was used to collect 1~10μm aerosol particles onsite for following nucleic acid extraction. A fluorescence aerosol particle sensor (FLAPS) was also applied to identify the fluorescent particles in diameter of 1~10μm for the biological warning in possible. In the PCR results from different time-point aerosol collection, the nucleic acid concentration from the collected sample of 30~40min was the optimal condition for PCR electrophoresis. Comparing the results of gel electrophoresis shows that the ammonium acetate method we modified in this project for nucleic acid extraction was proved more efficient than the commercial genomic DNA extraction kit. In the results of the next generation sequencing showed that the total nucleic acid extraction from a single sample was too low to construct a library for NGS. We still try to overcome the difficulty and reboot all the samples for test. Then we combined with the air particle counter in this experiment to develop a set of equation for conversion of XMX sample volume to the particle number at the location. Comparison the data from monthly average number of detected fluorescent particles and the weather information, such as temperature, humidity, and wind speed, which correlated with fluorescent particle numbers and the climate apparently. These data were also important references in aerosol baseline. Base on the well-established sampling and analytical methods described above, this plan can be applied to verify its viability for 1 to 2 years. It can build the biohazardous database in the air background, and then to utilize in biological early warning system.

Keywords: aerosol biohazards, bacteria, fungi, metagenomics, next generation sequencing, air sampling module, fluorescence aerosol particle sensor, biological early warning system

壹、前言

一、研究問題之背景與現況

空氣是生物存活的重要元素之一，其由不同比例的氣體組成，當中尚包涵肉眼可見與不可見之成分物質，如懸浮微粒、化學物、微生物等等，其成分改變可能影響生物體之健康，甚至是生命危害，因此空氣監測作業至為重要。在台灣空氣監測作業行之有年，相關業管單位如行政院環境保護署，即於本島北、中、南、東等城鎮設置定點監測站，執行常態性空氣品質監測作業與紀錄分析，其主要針對空氣中懸浮微粒PM10及PM2.5(particulate matter, PM)、污染物及化學成分等進行完整之空氣品質監測與分析。此外中央研究院所屬之環境變遷中心亦進行空氣品質之監測、分析，其研究目的乃是針對台灣工業化後區域氣候變遷之問題與都市熱島效應對區域氣候的影響進行探討與分析，並不同於環境保護署監測目的。

於環境保護署監測之空氣品質項目中，PM2.5即指粒徑在2.5μm以下的細顆粒物，易進入生物體呼吸系統造成危害，其主要來自人為排放與燃燒過程，在空氣中轉化成PM2.5的氣體污染物主要有二氧化硫、氮氧化物、氨氣、揮發性有機物，也是環保署空氣品質監測之項目。此外，還有各種灰塵、花粉等由於顆粒小吸入後可直接進入肺泡並被巨噬細胞吞噬，亦可能停留在肺泡內造成呼吸系統、心血管、神經系統等之影響，而這些顆粒通過支氣管和肺泡進入血液時，其攜帶之有害氣體、重金屬等若溶出至血液中，對健康傷害甚鉅，故近年公共衛生、職業衛生、環境衛生等領域大多聚焦於PM2.5之危害影響之研究。而PM10係指粒徑在10μm以下之空氣懸浮微粒或稱浮游塵，主要來源包括道路揚塵、車輛排放廢氣、露天燃燒、營建施工及農地耕作等，或由原生性空氣污染物轉化成之二次污染物。此類10μm以下微粒吸入後亦能進到肺臟深處沉積，如該粒子附著其他污染物，則將加深對呼吸系統之危害。

而空氣當中除上述化學污染物以外亦存在生物性物質，其來源常見為細菌、真菌或是其孢子等，而病毒雖可能懸浮於空氣中，但因病毒脫離宿主後存活時間短，故常態之空氣背景幾無病毒存在，因此本計畫之技術發展設定目標於細菌與真菌之測得與分析，本次資料建立並未納入病毒之檢測。可懸浮於空氣之生物性物質大約為1~30μm間(病毒除外)，然當前多受限於樣本收集工具選擇性少，樣本分離、分析鑑定技術耗時久等

因素，空氣組成中化學成分以外之生物性危害物質未大量發展與受到重視，遑論建立空氣中常態之生物性危害物質背景，在我國此空氣背景相關之研究報告鮮少，且目前多數之空氣中生物物質分析仍以培養基鑑定方法進行，國內尚無利用次世代基因定序技術於空氣樣本分析，故此部分技術發展為本計畫發展之目標，本年度因執行期程較短，計畫目標設定於採樣及樣本分析等前置方法之建立，次年始為方法驗證與完整之背景值偵測與資料庫建立，另本計畫目標亦會蒐集生物預警系統資訊及說明，俾提供後續計畫委託單位之購置評估參考。本計畫規劃建立空氣檢體採樣技術、空氣懸浮粒子樣本中之生物物質分析之分子生物技術，輔以瓊脂培養結果，初步分析與判定檢體中之細菌、黴菌等生物物質為目標，於方法建立後再進行條件最佳化，俾適用於實況作業需求。

如下表所列，空氣中生物懸浮微粒之來源甚多，植物花粉或孢子都是可能存在之生物性微粒，然而具生物性危害之物質仍多以微生物為主，如細菌、病毒與真菌等，這些物質於常態之背景中存在量推估極其微少，若未經過培養則須收集更大總量之空氣方利於後續之分離與鑑定分析。而這類氣粒性生物物質多具有蛋白質外鞘，若藉由固定波長之雷射光源激發生物性顆粒體，則可能得到一螢光訊號與形狀，藉此區辨生物與非生物性，初步篩選出可能具有螢光之懸浮氣粒，正是生物預警系統之發展理論基礎之一，而此類技術應用在空氣背景與工程之跨領域之研究相當熱門，實際應用於檢測之技術亦日新月異，故相關發展進程值得參考[1-4]。

表1、空氣中可能存在之生物懸浮粒子來源[5]

Particle	Natural Sources	Source Characteristics	Man-made Sources	Source Characteristics
Viruses	Infected organisms	Probably ubiquitous	Sewage, other?	Point sources; sporadic
Bacteria and related particles	Living leaf surfaces	Ubiquitous	Sewage	Point or line sources, sporadic
	Dead leaf surfaces		Compost	
	Water		Cooling towers	
			Biopesticides	
Fungal particles	Mushrooms, puffballs	Ubiquitous	Compost	Point sources, variable
	Infected plants		Infected agricultural products	
	Dead plants			
	Fecal material (i.e., animal droppings)		Colonized dead field crops	
	Water		Stored dead organic material (grain, straw, etc.), biopesticides	
	Soil			
Pollen	Vascular plants	Ubiquitous	Agricultural plants	Large point sources, variable
Other plant particles	Ferns, mosses, clubmosses, horsetails, mosses, liverwort, algae	Cosmopolitan, variable	Horticulture, aquaculture, seed/grain powders	Small area sources, variable
Other aerosols	Arthropods	Cosmopolitan, variable	Sewage, stored food	Point sources

承上所述，空氣菌叢(airborne bacterial community)資訊即為空氣中一基礎且重要之微生物背景知識，結合設置背景資料庫於上述生物預警系統，並依據此基礎資訊之瞭解與比對，始可在於短時間內快速、準確判斷異於常態分佈或單點異常大量產生之微生物散佈。當前如美國、挪威等國家均早已起步發展[2, 6-8]，並投注於此類背景資料之建立與檢測技術發展，據以為空氣異常變化時可供對照，以便即早偵測與應變處置。而建置資料庫之地點應區分室內、外空間，如城市據點、地鐵站、車站等大眾易聚集之場所。而空氣採樣之樣本品質首要在於採樣儀器之效能良窳，就國內現有之空氣採樣儀器選擇性不多，本計畫選用之XMX 2A/2AL為一可快速、大量收集空氣樣本之高性能儀器，其藉由每分鐘600-800公升之進氣量，將高量體積之空氣壓縮液化於5毫升純水中，以利後續之檢測分析，同時亦降低取樣時空氣懸浮粒子再度飄揚之危害性，然而其缺點為無法電池供電，且不具有粒子分析、計算或預警之功能，但仍適合用於空氣背景資料分析使用，是以本計畫便規畫運用此XMX收取樣本後進行分析。

在樣本之後續檢測與鑑定技術上，傳統微生物技術中欲分析臨床樣本或環境檢體之微生物係藉由培養基選用、生長、分離與後續之生化鑑定來達到辨鑑目的。然而培養基鑑定並不適用於部分菌種，即使是常見於細菌培養之營養瓊脂培養基(Nutrient agar, NA)、海克頓瓊脂培養基(Hektoen enteric agar, HE)或腦心浸液培養基(Brain-heart infusion medium agar, BHIA)培養基等仍無法適用所有菌種培養，然而部分高致病原細菌或真菌需特殊營養成分，需使用含綿羊血之瓊脂培養基(Blood Agar Plate, BAP)始能良好生長，故本計畫中仍利用此培養基進行培養，以避免遺漏空氣中致病性生物病原。此技術雖費時、耗力，但其優點為鑑定結果準確，不易誤差，故仍是目前臨床檢驗作業之標準方法；其缺點則是培養基長不出之菌種即無法發現與鑑定，在面對未知菌種時即無法得到全面、精確之分析結果。由於近代分子生物技術之快速發展，如PCR及real-time PCR技術，使得細菌菌種鑑定可藉由特定設計之引子放大16S核醣核酸(16S ribosomal RNA)區段並於基因層次區辨菌種，real-time PCR更可藉由螢光強度進行定量，為微生物分析之重要工具。如同常見之土壤與水之環境樣本分析，本計畫中欲建立之空氣樣本採集分析亦屬環境生態分析之一環，而鑑於空氣中常態存在之生物性背景物質應為細菌與真菌等微生物群落，故本計畫亦規畫結合分子生物技術遂行空氣中之生物物質分析，藉以瞭解選定基礎設施位置之室內、外空氣中存在之微生物種類、數量與分佈，俾建立基礎數值。自4月份接獲本計畫後，本實驗室初步階段規劃完成及參考國內、外相關研究文獻蒐整，

除進一步瞭解常見環境檢體中微生物之採樣、核酸萃取、鑑定分析及空氣中微生物分析方法，據以執行實驗測試，並建立我國適用之空氣中生物性背景值檢測法，以提供後續規劃生物預警系統之前測試與評估。

故本計畫於執行初始開始蒐集國內、外之參考文獻，鑒於於環境樣本中生物物質監測之研究常見為土壤與水中之微生物分析，此類研究發展多時，且當前多應用分子生物方法進行微生物之菌相鑑定，其無論於樣本收集方法、核酸萃取、引子設計至資料分析皆具參考價值[9-13]。其微生物鑑定之引子設計部分，細菌多是藉由16S核醣核酸(ribosomal RNA, rRNA)保守引子與5.8 S核醣核酸附近之核內內轉錄區間(internal transcribed spacer, ITS)特異性引子之發展，分別對於土壤中之細菌及真菌進行PCR片段放大、序列比對與菌種分析，然而傳統PCR受制於技術限制，僅能藉由核酸片段電泳確認單一菌種，欲鑑定不同菌種則需發展各式專一引子以進行多重性聚合酶鏈鎖反應(multiplex PCR)來達到目的，縱使如此仍無法以概觀檢視樣本中之菌種分佈與數量。在早期之環境檢體相關研究中，針對空氣中生物性物質之研究文獻稀少，故相關實驗參考缺乏，就目前本計畫蒐集之相關文獻亦大多聚焦於特定室內空間之細菌種類分析與培養基選定之探討[14]。這些文獻中所鑑定出之空氣菌種多為常見細菌，究因於此結果導向可能因運用之採樣與培養方法導致實驗誤差(bias)。以50-60年代之文獻為例，其通常是以大量培養基收集落菌檢體後進行培養，最終所得到之鑑定結果卻相當有限，因為誠如上述，部分菌種培養條件與營養需求不同，在選用培養基時作者已人為篩選了部分微生物，導致結果偏差，然而此為當時微生物知識與技術發展之先天限制無法避免。就最早發表於1956年Journal of Hygiene期刊之文獻中所述[15]，當時的假說認為空氣中分佈之細菌與上呼吸道疾病之傳播相關，因此針對學校教室的空氣進行菌落培養，其針對英國某地區數個學校教室以培養基收集落菌方式，長出菌落後進行空氣菌種鑑定與分析，其中29個空氣檢體培養之菌落鑑定中計有微球菌(Micrococci)、空氣球菌(Aerococci)、鏈球菌(Streptococci)、白喉菌 (Diphtheroid organisms)、桿狀菌(Coliform organisms)、菌孢子、金黃色葡萄球菌(Staph. aureus)等七類菌種和其他無法分類之菌落，其中約80%為微球菌，白喉菌數量次之，成果相當具體且重要，仍是為今日空氣生物性物質監測之先驅與實驗性研究。之後至70年代間空氣檢體之相關研究仍然稀少，該時期間尚有針對醫院及潛艦之侷限空間內空氣微生物檢測研究[16, 17]，然而受限於空氣採樣技術與細菌培養、鑑定技術等因素，此類耗費研究耗費人力、物力，成果卻相當有限。70年代後基於微生

物檢測、生化鑑定技術之發展成熟，此類空氣中微生物之研究結果亦可獲得更完整之訊息，無論在醫院工作場所或是各動物養殖場所均有相關之研究發表，其結果測得之菌相亦可發現隨著檢測之環境特性確實有所差異[18-20]。直至80年代中旬聚合酶鏈鎖反應(polymerase chain reaction)之出現及發展，使得菌種鑑定技術亦提升至分子生物層面，結合ribosomal RNA之特性，已廣泛應用於原核生物之系統分類與微生物學鑑定等方面之研究[21-24]，本計畫中即是運用ribosomal RNA區段之特異引子用於樣本中生物物質之初步偵測。

核醣核酸(ribosomal RNA)在生物體中廣泛存在，其分類係依沉降速率不同來區分，無論在真核生物或原核生物的演化上均扮演重要角色。隨著分子生物學上對於rRNA之瞭解，如原核生物之於16S rRNA、真核生物之5.8S、18S及28S rRNA等基因區段之重要性與功能性，其應用層面更為廣泛，不僅在菌種演化與分類學上具發展潛力，更可應用於臨床檢測或環境監測等領域。在原核生物中ribosomal RNA分類少、數量多，演化過程在基因組結構上不若真核生物具高度重複序列，在其序列結構與功能上均相對保守，加上細菌中的rDNA在染色體上常以多拷貝(copies)形式存在並與生長速率相關，如大腸桿菌中的rDNA就具7份拷貝、枯草桿菌具10份拷貝等，這些拷貝數更是被當提升目標基因之利基。在原核生物中，rRNA可依其高速離心時之沉降速率(S)區分5S、16S和23S等三類，其中原核生物的16S rRNA為30S次單元之一部分，編碼基因(rDNA)序列長度約1,540 bp[12]，相對於5S rRNA約120 bp或23S rRNA約3,300 bp，前者序列短，所提供之資訊不足以應用分析，後者雖然序列較16S長，但其鹼基變異速度快，不適於用作演化分析或鑑定依據，基於上述因素，16S rRNA鹼基序列長度適中，在菌種演化上亦具有高度保守性(highly conserved)，是最常被應用於菌種鑑定與演化分析之rRNA，於微生物學上佔有重要之地位，近年結合分子生物技術之發展，廣泛應用於臨床菌種檢測與其相關研究[25-30]。16S rDNA則是細菌染色體上編碼rRNA相對應之DNA 序列，全長包含保守區段與變異區段，亦是廣泛應用的微生物檢測目標基因。首先編碼16S rRNA的基因與細菌染色體上大多數基因相比具有高度保守性，而此基因保守性是相對的，在保守區之間存在9段高變異區(hypervariable region, V1～V9)，不同科、屬、種間之微生物都有不同程度的差異。因此，將藉由16S rRNA的保守和特異區段間之交互確認，依目的設計觀察其中一區，常見於微生物之分子生物診斷應用。以本計畫而言設計特異引子於保守區

段，用以觀察變異區段(hypervariable region)，希望藉由比對變異區段鹼基差異與基因庫比對，達到分析同一樣樣本中細菌菌種之目標。

另本研究中亦規劃以另一對特異性引子同時在空氣樣本中分析真菌(fungi)，近年自環境中檢測真菌之分子生物技術成熟，包含PCR、real-time PCR及NGS等等[8]，其中特異引子之設計莫過於rRNA區段間內轉錄間隔區(Internal transcribed spacer, ITS)之應用。故本計畫中針對真菌檢測之引子正是介於16S與23S rRNA區段間之內轉錄間隔區(Internal transcribed spacer)之ITS引子。由於真菌核糖體基因由18S、ITS1、5 .8S、ITS2及28S rRNA構成，頭尾串聯形成重複序列、基因序列上高度保守，單個基因組內具60～200份拷貝，一般ITS長度約在650～750 bp。然而真核生物演化過程中成熟核醣體並不出現在ITS區，故ITS片段在進化過程中可容忍較多變異、序列變化快，由此可表現出廣泛之序列多態性，藉由此序列比對差異即可鑑定親緣關係接近之真菌菌種，在微生物之分類鑑定、系統發育及結構演化上相當重要，從這些ITS序列可觀察異種之同源性。ITS片段的進化速率約是18S rDNA的10倍，此基因序列變化之差異正是真菌種類鑒定和群落分析的基礎。故針對真菌之偵測大多是利此ITS區段進行引子設計，如ITS1、ITS4等即為常見之特異引子。90年代ITS序列開始研究應用於植物Mimulus guttatus之分類[31]，後續應用ITS於真菌分析之研究發表亦不多[32]，直至近年ITS結合最新分子生物技術用於真菌鑑定或分類之研究陸續發表[33-37]，且解析效果佳。是以本研究中即參考上述文獻，並由ITS1和ITS2兩區段設計特異性引子，其優點為兩者間涵蓋5.8S rRNA，為中度保守區域，由於其保守性出現於同菌種內、菌間差異明顯，因此適用於全基因組之真菌菌種分類。且ITS序列片段相對較小，也易於分析，故早已被廣泛應用於真菌屬內不同種間或近似菌屬間的系統發育研究，而本計畫則僅是單純應用於樣本之真菌鑑定使用。

近年次世代基因定序(next generation sequencing, NGS)結合上述特定核醣核酸區段引子與PCR放大子(amplicon)之全基因組(metagenomics)技術大量被應用於微生物檢測分析之研究，無論是食品、環境生態、臨床檢驗、動物或是人體口腔等性質各異之檢體，均可利用NGS技術解析檢體微生物組成與差異性[8-16]，其相較於以往之微生物鑑定技術其所得出之分析結果更為全面且廣泛，藉由定序比對不僅可區辨菌種差異，更可瞭解其於檢體中之組成分佈與相對比例，符合本計畫之目標需求。次世代基因定序技術出現之前，環境全基因組學(environmental metagenomics)發展相當侷限，雖然其分析包括來自湖水、深海火山口的水樣本或土壤樣品的微生物種群，且分析結果可廣泛應用於農業

微生物組分析、生態修復，或其他的生物學研究，然而此一基於環境樣品中的DNA分析及生物體中微生物群落之研究不僅廣泛，且不易聚焦，或是所得到的資訊片段無法綜觀等缺點無法克服。次世代基因定序技術之優點讓研究人員能夠分析複雜樣品中的整個微生物群落，發現新的生物，並探索不斷變化的條件下微生物種群的動態性質，已是目前最廣泛應用於生物巨觀資料之技術，其高通量(high-throughput)與高解析度(high-resolution)之特性，使其應用範圍已遍及基因體學、生物醫學、環境科學等領域。

二、研究目的

(一) 發展我國之空氣採樣技術、空氣懸浮粒子樣本中之生物物質分析之分子生物技術，輔以瓊脂培養結果，初步分析與判定檢體中之細菌、黴菌等生物物質為目標。

(二) 規劃導入次世代基因定序之技術應用，以全基因組與放大子概念進行空氣樣本之生物性物質監測與基礎數值建立，進而從中瞭解細菌/真菌菌叢與氣候因子之背景變化趨勢與相關性。

貳、材料與方法

一、實驗材料與試劑

材料與試劑名稱	來源公司	產品編號
Tris Buffer, 1 M, pH 8.0	Amresco (Solon.OH,USA)	E691
Ammonium Acetate	Sigma (Solon.OH,USA)	B0486
PBS, 1X, pH 7.4 (GIBCO)	Invitrogen (CA, USA.)	883001
Ethanol (for molecular biology)	Merck (Darmstadt, Germany)	108543
Ethanol absolute (for analysis EMSURE® ACS)	Merck (Darmstadt, Germany)	100983
Ultra-pure DEPC (diethylpyrocarbonate) water	Protech (Taipei, Taiwan)	PT-P560
Albumin from bovine serum(BSA)	Sigma (St.Louis,USA)	A7906
LB agar (powder)	Sigma (St.Louis,USA)	L2897
LB(Luria-Bertani) broth tablet	Sigma (St.Louis,USA)	L7275
Phenol: chloroform: isoamyl alcohol 25:24:1 (for molecular biology)	Sigma (St.Louis,USA)	P3803
Sodium dodecyl sulfate（SDS）	Sigma (St.Louis,USA)	L3771
Sodium chloride (NaCl)	Sigma (St.Louis,USA)	S7653
BioHAZ™ Kit	EAI Corporation	
DNA MW Standard Marker-λ-Hind III digest(23130~125kd)	Takara Biotechnology	3403
DNA MW Standard Marker-D2000(2000~100kd)	Tiangen Biotech	MD114
Proteinase K	Tools 圖爾思生技	
PLGel Heavy 2ml	Tools 圖爾思生技	
Blood Agar Plate (BAP)	Creative 啟新生技	
Qubit® dsDNA HS Assay Kit	Invitrogen 萊富生命科技	dsDNA HS
PCR 引子合成(16S, ITS primer)	Genomics 基龍米克斯	

二、實驗儀器與方法

(一) 實驗儀器

儀器/設備名稱	公司	型(編)號
微量滴管(2, 20, 200, 1000 µl)	GILSON (力明)	PIPETMAN Classic™
紫外光分光光度計(UV spectrophotometer)	GE HEALTH	GeneQuant 1300
分光光度計(Double-beam spectrophotometer)	CHROMOTECH	CT-8200
酸鹼度測定器(pH meter)	HANNA	PH-211
電子微量天秤(High precision balance)	MONOBLOC	AB204-S
去離子水製造系統(Water purification system)	MILLIPORE	Milli-Q A10
高壓滅菌釜(Steam sterilizer)	YTM 大正和	YTM TCH
迴轉式震盪培養箱(Orbital shaking incubator)	TKS	OSI-511R
迴轉式震盪器(Digital orbital shaker)	HEIDOLPH	Unimax 1010
旋轉式震盪器(Rotary shaker)	WHEATON	T-102
試管震盪器(Vortex mixer)	VORTEX-GENIE2	
烘箱(Oven)	SHEL LAB	VWR 1535
高速離心機(High speed centrifuge)	HERMLE	Z233MK-2
XMX 空氣採樣器(Air particles concentrator/ Liquid impingement module)	DYCOR	XMX/2A, XMX/2AL
動力式螢光雷射氣粒偵測系統(Air particles concentrator)	DYCOR	FLAPS-II
空氣粒子計數器(Aerosol particle counter)	ROYCO	Model 325
手持式 ATP 冷光檢測儀(ATP luminescence detection instruments.)	New Horizons Diagnostics	Model 4700
Qubit fluorometer 核酸/蛋白質定量儀	Life Technologies, Invitrogen	Qubit® 2.0

(二)實驗方法

本計畫應用高通量空氣採樣技術配合全基因定序技術與序列比對,後續可能使用於北區空氣採樣地點設定於某重要設施處所,運用 Dycor 之 XMX 手提式空氣採樣器進行空氣樣本採樣及液化,此儀器包含 XMX/2A 及 XMX/2AL 兩部分組成, 前者 XMX/2A 功能主要為 particle concentrator,藉由吸入大量空氣後裝置煙囪以孔徑篩選、迴旋離心等方式區分空氣粒子粒徑,並收入 1~10μm 大小之空氣粒子注入後者 liquid impingement module 之模組中,故 XMX/2AL 功能主要為將上述高量 1~10μm 之空氣粒子樣本高壓注入裝有純水之 50ml 收集管內濃縮液化。此採樣作業每月之月底前擇日收集乙次,用以進行空氣粒子中之生物物質分析。詳述如下

※ 空氣檢體收集

(1)檢體採集使用之儀器:

i. 空氣粒子濃縮採樣器(XMX/2A-air particles concentrator, XMX/2AL-the liquid impingement module):此採樣儀器包含 XMX/2A 及 XMX/2AL 兩部分組成: 前者為空氣粒子濃縮器,後者為空氣液化收集模組,啟動時由上方煙囪口以每分鐘 600-800 公升之體積,吸入周邊空氣並藉離心力,篩選設定 1-10 μm 大小之空氣懸浮粒子濃縮,送至收集模組使以濃縮之空氣粒子經末端噴嘴注入 50 毫升離心管之緩衝液體中,避免粒子再度懸浮飄散造成污染風險。

ii. 空氣粒子計數器(Laser Particle Counter Model 325, Royco):收集紀錄 30 秒間 0.5-10μm 粒徑大小的懸浮粒子,並分別顯示當中 0.5、1、2、3、5、10μm 粒徑空氣粒子之累積數量及加總數,機器設定自動運作,設定自動收集,每次收集 30 秒,連續收集 2 次。

iii. (2)採集之作業方式:

i. 當天於三處固定之定點採集空氣粒子樣本,除用於條件最佳化測試之首次樣本,收集 5、15、20、30 及 40 分鐘,據以分析收集時間最佳化之條件。

ii. 經由條件最佳化後,係以每次 30-40 分鐘採樣之檢體樣本濃縮量為最佳,故實驗樣本係以各定點收集 40 分鐘(收集速率為 600-800 公升/分鐘)約收集總量 24000~32000 公升之濃縮空氣液化於 5ml 體積之無菌純水中,以利進行後續實驗與數據分析。另使用空氣粒子計數器 (Laser Particle Counter Model 325,

Royco)，測定採集點定點、定時之空氣粒子數(收集效率 28L/min)，提供後續空氣採樣器之數據換算。

iii. 繼以特殊設計之 16S 核醣核酸引子對與 ITS 引子對多組，分別進行聚合酶鏈鎖反應完成特定區段放大子，於放大子兩端分別接上辨識之 barcode，再以次世代基因定序儀進行上述核酸片段之全定序與資料庫序列比對，預期可得到空氣中已知細菌與真菌之組成分析等基礎數值。

※檢體前處理與核酸萃取步驟

(1)空氣樣本前處理

每管檢體係藉由 XMX 儀器(如圖 1)濃縮空氣收集於 5ml 去離子水中(裝於 50 ml 離心管)，再分裝至 1.5ml 微量管中，高速離心 5min 去除上清液，重複上述分裝、離心步驟，將收集之檢體離心濃縮集中管底，以進行核酸萃取。步驟如下：

1. 收集後之空氣檢體依上述濃縮步驟將菌體收集於同一 1.5ml 之微量離心管
2. 離心 13,000 rpm, 5min。
3. 小心移除上清液，保存管底之菌體 pellet。
4. 加入 500µl digestion buffer (內含 10% SDS), 10µl of proteinase K(20mg/ml) 及 10µl of lysozyme(100mg/ml)
5. Vortex 震盪 30 秒。
6. 靜置 55℃加熱 30 分鐘，俾使菌體完全溶解。

圖1、空氣微粒濃縮收集器-型號 XMX-2A/2AL(DYCOR, Canada).

(2)核酸萃取步驟

※醋酸銨-氯仿(Ammonium acteate-chloroform)核酸萃取法純化核酸

1. 再次加入 10μL proteinase K(20mg/ml)及 10μL lysozyme(100mg/ml)
2. 震盪 30 秒混合均勻，55℃再加熱 30 分鐘。
3. 上述檢體混合液加入 200μl Chloroform 與 200μL Ammonium acetate(濃度 8M)後，手動搖晃均勻，再全數移入 Blocking PLAGEL 管中。
4. 震盪混合 30 秒，接著以 12,000 rpm 離心 5 分鐘使分層。
5. 取出上層清澈水液部份至 1.5ml 微量離心管。
6. 加入 5 μL 1% Linear polyacrylamide(LPA)與 550μL Isopropanol
7. 手動搖勻，靜置室溫 5 分鐘後，以 13,000rpm 離心 5 分鐘。
8. 去除上清液，再加入 600μL 70% ethanol。
9. 13,000rpm 離心 3 分鐘後，再移除上清液，留下管底 pellet。
10. 吸附多餘液體，置管底之菌體 pellet 於室溫下完全乾燥，保存於-20℃冰箱待用。
11. 使用前再以 20-25μL TE buffer(或去離子水)回溶，俾用於檢測。

※以 QIAamp DNA Mini Kit 抽取全基因體核酸(genomic DNA)

1. 依檢體種類進行處理：
   (1)取 180 µl 之 Buffer ATL ，由 BHIA 上挑起數個菌落後懸浮於 ATL 中，vortex。
   (2)取 200 µl sample，離心 12000 rpm, 1 min，去除上清液後，將 Pellet 懸浮於 180 µl 之 Enzyme solution，vortex。
2. 37℃靜置 30 min。
3. Spin down, 加入 20 µl Proteinase K 及 200 µl Buffer AL，vortex 均勻。
4. 56℃靜置 30 min。
5. 95℃靜置 15 min 。
6. Spin down。
7. 加入 200 µl ethanol (96-100%)，震盪 15 秒，spin down。
8. 將 QIAamp Spin Column 插入 QIAvac vacuum maniford 的 VacConnector，小心地將步驟 7. 之 mixturer(若有沉澱物，也一起加入)加入 QIAamp spin column 中，採用離心方式，將 QIAamp Spin Column 放入乾淨的 2 ml tube，離心 10000

rpm，1 min。

9. 加入 500 µl 之 Buffer AW1，離心 10000 rpm，1 min。
10. 加入 500 µl 之 Buffer AW2，小心勿溢出，離心 12000 rpm，3 min。。
11. 將 QIAamp spin column 蓋子蓋上，將 QIAamp spin column 移到另一個乾淨的 2ml 收集管，丟棄 VacConnector，離心 12000 rpm，1 分鐘，讓 QIAamp spin column 內的濾膜完全乾燥
12. 將 QIAamp spin column 移到另一個乾淨的 1.5 ml 微量離心管，丟棄原收集管，打開 QIAamp spin column 的蓋子，加入 100 µl 之 10 mM Tris, pH8.0。
13. 室溫靜置 5 分鐘，離心 10000rpm，1 分鐘。
14. 測定 DNA 濃度後保存於-20℃。

※DNA 定量: HS dsDNA Assay kit and Qubit® 2.0 fluorometer

1. 製備 dye Working Solution

   每一檢體取用 199 µl buffer，每一檢體取用 1 µl dye，利用震盪器混合均勻
2. 將 190 µl 之 dye Working Solution 分裝至兩支 0.5 ml 分析管中，以備標準品使用。
3. 各加入 10 µl 標準品，利用震盪器混合均勻。
4. 將 180-199 µl 之 dye Working Solution 分裝至 0.5 ml 分析管中，以備檢體使用。
5. 各管加入 1-20 µl 之檢體，各管之最終體積應為 200 µl，利用震盪器混合均勻。
6. 室溫靜置 2 分鐘。
7. 以 Qubit® 2.0 fluorometer 測定數值。

※PCR 放大及 adaptor 接合

以 GenBank BLAST 比對分析 ITS 及 16S rDNA 引子與探針序列的特異性(探針序列如下表所列)，再用於聚合酶鏈鎖反應，同時於引子一端分別接上 Illumina NGS 特定之 adaptor 序列以利進行後續 NGS 定序。上述測定後之核酸產品加入引子進行聚合酶鏈鎖反應，並加入特定引子以放大特定區段之放大子(amplicon)。PCR 反應條件如下:

• 95°C for 3min
• 30 running cycles of:

— 95℃ for 30sec

— 55℃ for 30sec

— 72℃ for 30sec

• 72°C for 5min

• Hold at 4°C

※本實驗應用於 PCR 反應之特異引子(primer)與放大子(amplicon)位置區段

表2、本研究中所使用之 PCR 引子及其序列列表

標的(目標基因)	引子名稱	引子序列(5'→3')	參考文獻
Bacteria (16S rRNA)	V3-338F	ACTCCTACGGGAGGCAGCAG	[37-42]
	V3-534R	ATTACCGCGGCTGCTGG	
	V4-519F	TGCCAGCAGCCGCGGTAA	
	V4-806R	GGACTACARGGTATCTAAT	
Fungi (internal transcribed spacer, ITS)	ITS1	TCCGTAGGTGAACCTGCGG	[33-35, 43, 44]
	ITS2	GCTGCGTTCTTCATCGATGC	

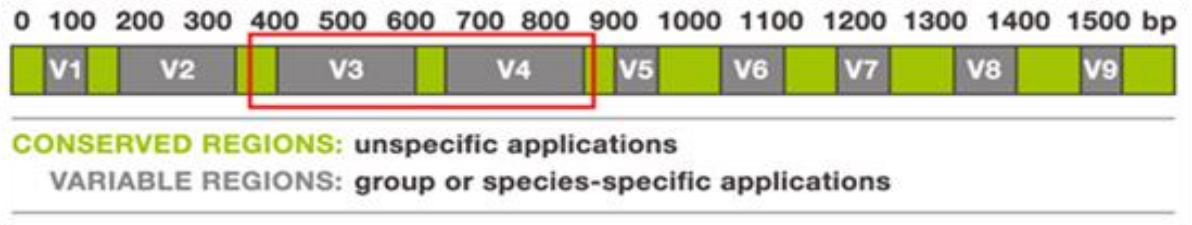


圖2、本研究用於細菌之特異引子 V3 及 V4 與放大之 16S rDNA 區段相對位置圖示（參考自網站: www.alimetrics.net）

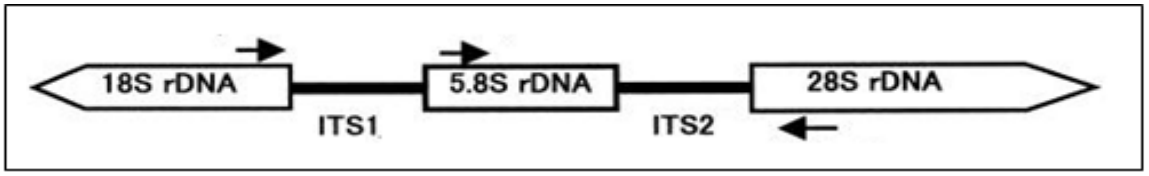


圖3、本研究中之真菌引子 ITS1 及 ITS2 與放大之 5.8S rDNA 區段相對位置圖示

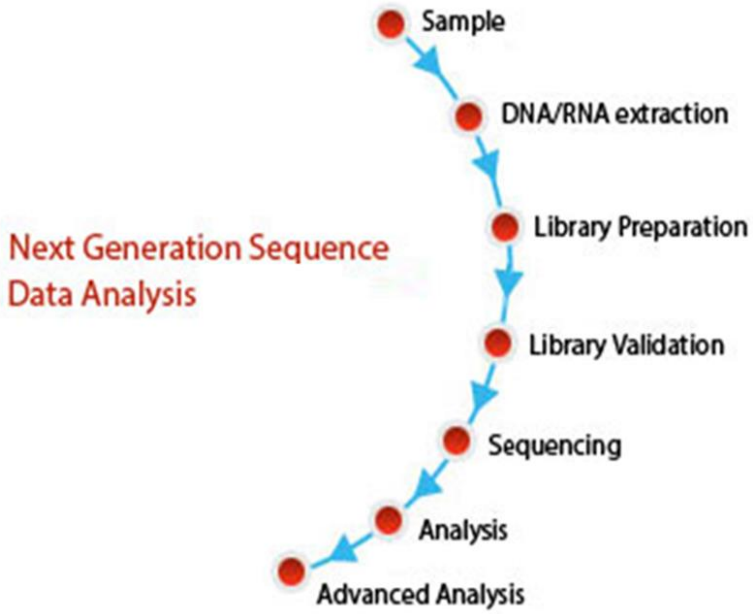
※進行次世代基因定序(Next-generation sequencing)與序列資訊分析

1.檢體準備：檢測上述步驟萃取之檢體核酸總量是否符合所需濃度。

2.序列庫創建(library preparation)與濃度確認

2.以 Illumina MiSeq 機型上機進行雙端(pair-end)定序

3.定序結果分析、序列比對與整理（16S 資料庫 Greengene databank）。



參、結果

一、空氣採樣時間與核酸萃取方式最佳化測試

(一)採樣時間最佳化測試

本計畫雖使用 XMX 空氣採樣器進行高通量之空氣粒子樣本採樣，經詢問儀器原廠建議，若於高濃度危害時樣本設定收樣時間為 5 分鐘；然而本計畫目的為監測空氣背景值之生物物質，推測於常態狀況下空氣中生物物質（如細菌）濃度極低，且鑒於各式空氣採樣氣效率不同，故欲由採樣檢體中測得有效之生物樣本濃度，仍需藉由不同時間點收集樣本進行前測試確認，以瞭解樣本中之生物物質濃度，並達到採樣時間最佳化之目標。故本計畫中首先以樣本中之細菌為偵測目標，利用其 16S 引子（詳見材料與方法）進行 PCR 反應，再由 PCR 產物之膠體電泳結果回推樣本中可能之細菌量，據以為樣本中生物物質之含量測試。結果如圖 4，最左邊為 DNA Ladder，Lane 1~Lane 5 為空氣採樣時間最佳化測試之膠體電泳結果，分別為收集 5、15、20、30 及 40 分鐘之檢體，以醋酸氨萃取方式同時進行核酸純化後，以 16S 引子進行 PCR 反應，55℃ 進行 35 個循環放大後之電泳結果，圖 4 中收集 5 分鐘及 15 分鐘之檢體最終 PCR 產物量偏少或無，而 30-40 分鐘（Lane 4 與 Lane 5）之 PCR 產物明顯。

(二)核酸純化方法選用及最佳化

本計畫雖採用高通量之空氣濃縮收集儀器，進行空氣檢體採樣，然而推測空氣中之背景菌量可能微量，實驗過程之誤差都可能造成後續實驗結果偏差(bias)或無結果，故就核酸純化方法部分，本研究選擇以修正自酚-氯仿之化學萃取方式與市售之核酸萃取套組進行結果比較，俾為後續之方法最佳化。圖 4 中，Lane 6 及 Lane 7 為兩種核酸純化方法之結果比較，就同為 40 分鐘連續收集之檢體，以本研究所修正發展之醋酸氨(Ammonium acetate)萃取方法與市售之核酸純化套組，同時進行核酸純化後以 16S 引子進行 PCR 後之膠體電泳結果，市售之核酸純化套組萃取後進行 PCR 之最終產物訊號微弱，而醋酸氨萃取法之 PCR 產物膠體電泳訊號明顯優於市售之核酸純化套組，可用於本計畫之核酸純化。

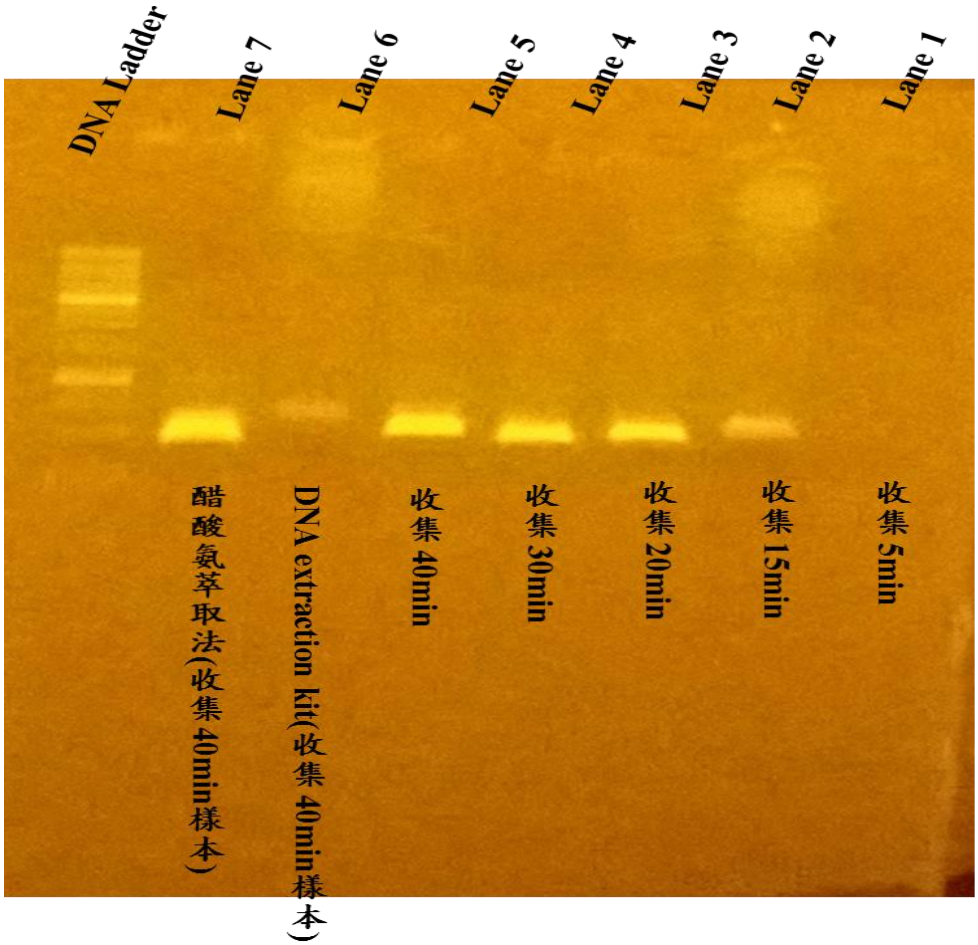


圖4、本研究中建立空氣採樣時間與核酸萃取方式最佳化測試之膠體電泳結果

二、建立由 XMX 收集之空氣樣本體積估算空氣粒子數之轉換公式

由於本計畫中所採用之 XMX 空氣收集器僅單具空氣粒子採樣功能，但機器本身無法估算收集之氣粒數量，為便於空氣懸浮粒子收集後之計算分析，本計畫藉由空氣粒子計數器與空氣採樣器之交互應用之基本性能參數換算，可得出一轉換參數 $K_{tr}= V_{max}/28$，帶入公式計算後可用於 XMX 收樣體積與顆粒數之數值轉換。此 XMX 之空氣粒子收集體積估算顆粒數之轉換公式如下：

N_{ap}(估算之空氣粒子數) =

V_{max}(XMX 轉速對應之最大收樣體積)*T_{xmx} (XMX 實際收樣時間) *

[(N_{pr1}+ N_{rp2}) (Royco 計數器連續兩次收集粒子數加總之數值)*(V_{max}/28)]

其計算步驟與範例詳列如下：

1. 確認 XMX 之面板轉速數值對應之最大收樣體積（可參考 DYCOR 原廠之使用手冊），僅列出常用轉數數值及其對應最大收樣體積如下：轉速數值「5」對應氣粒收樣體積約 550 公升/分鐘；數值「10」對應氣粒收樣體積約 800 公升/分鐘。
2. 於開啟 XMX 收樣時，同時以 Royco 空氣粒子計數器進行兩次各 30 秒之收樣（機器內部設定固定每次收樣為 30 秒），列印粒子粒徑分佈與兩次之累積粒子數，若第一次收集數值為 N_{rp1}，第二次收集數值為 N_{rp2}，取兩次粒子數相加之總數（N_{pr1}+ N_{rp2}）。
3. 以 XMX 面板轉速數值 5，收集 40 分鐘為例，對應最大體積約每分鐘 550 公升，Royco 計數器兩次收集總數（N_{pr1}+ N_{rp2}）為 90000 顆。故推算 XMX 收集 40 分鐘體積轉換空氣粒子數 N_{ap} = 550*40 *90,000*(550/28)=**38,892,857,142**

三、本計畫於戶外定點收集之空氣懸浮粒子與即時螢光粒子分析

(一) 蒐集與選用本計畫 1~10μm 空氣樣本結果之環境參考背景資訊

本計畫欲建置之空氣生物危害物質背景係針對粒徑 1~10μm 間之空氣懸浮微粒進行定點收集與檢測分析，此與環保署 PM10 收集資訊相符，故首先蒐集北區觀測站 PM10 之定點資訊，並藉由比較其已建立之 PM10 資訊，選用地理與氣候條件相近之基礎值以作為環境之背景參考之應用；由於本計畫選定之定點採樣區位於新北市三峽地區，為選擇具參考意義之觀測站資訊為本計畫結果對照依據，以利引用其相關氣候因子數值進行後續比對分析，故本計畫蒐集鄰近三峽地區採樣定點 A 之四座觀測站 PM10 數據(如表 3)觀察其變化趨勢，表列相關資訊均節錄自環境保護署資料庫。圖 5 為 103 年 1~10 月之 PM10 每月平均數分佈繪製之折線圖，圖中 X 軸數值為月份，Y 軸數值為觀測站收集之 PM10 月平均數（計量單位: $\mu g/m^3$），比對結果可見以新北市之板橋與土城兩觀測站折線變化趨勢相近，且地理位置鄰近本計畫中採樣之採樣點—三峽地區，故選用此兩觀測站之資訊為本計畫收集結果之比對背景與數據參考基礎。

表 3、103 年 1~10 月間北區鄰近三峽地區採樣定點 A 之 4 個觀測站 PM10 月均數監測數據

監測項目	監測日期(年/月)	台北(中山)觀測站監測值($\mu g/m^3$)	板橋觀測站監測值($\mu g/m^3$)	土城觀測站監測值($\mu g/m^3$)	龍潭觀測站監測值($\mu g/m^3$)
PM10	103/01	79	62	60	69
	103/02	59	45	41	52
	103/03	73	60	56	67
	103/04	68	55	54	65
	103/05	56	43	44	50
	103/06	56	38	38	51
	103/07	47	33	35	42
	103/08	50	39	45	43
	103/09	49	36	41	42
	103/10	63	51	55	54

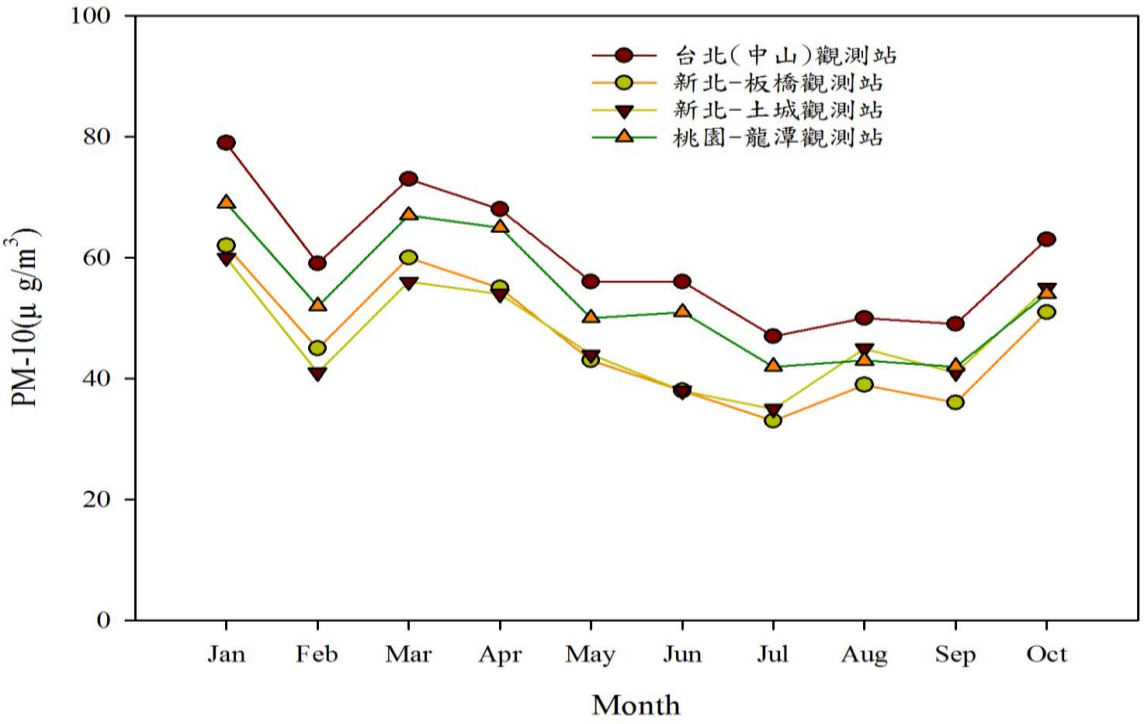


圖5、103 年 1-10 月北區四座觀測站 PM10 月平均數分佈趨勢比較

(二) 本計畫所收集定點之 1~10μm 空氣樣本與螢光粒子結果對照於環境背景資訊

本計畫依上圖 11 比較結果初步選定以新北-板橋與土城觀測站為本計畫之背景參考數據。相較於本計畫於三峽地區選定之 A 定點應用 XMX 空氣採樣系統高通量收集之 1~10μm 空氣粒子變化，輔以螢光空氣懸浮粒子感測器即時分析上述空氣粒子樣本中帶有螢光之 1~10μm 空氣粒子，以瞭解本計畫所使用之空氣採樣系統與觀測站之差異。圖 12 中，X 軸數值為月份，左側 Y 軸為本計畫定點 A 收集之空氣粒子月均量（計量單位: 10^5/hr），右側 Y 軸為觀測站收集之 PM10 月平均數（計量單位: μg/m^3），由圖 12 中之比較可發現，本所收集之空氣粒子月均數變化趨勢除 7~8 月略有差異，餘月份與兩觀測站之 PM10 變化趨勢接近，故本計畫所使用之空氣粒子採樣系統。而樣本當中即時測得之螢光粒子分佈趨勢則與 1~10μm 空氣粒子分佈趨勢相符。

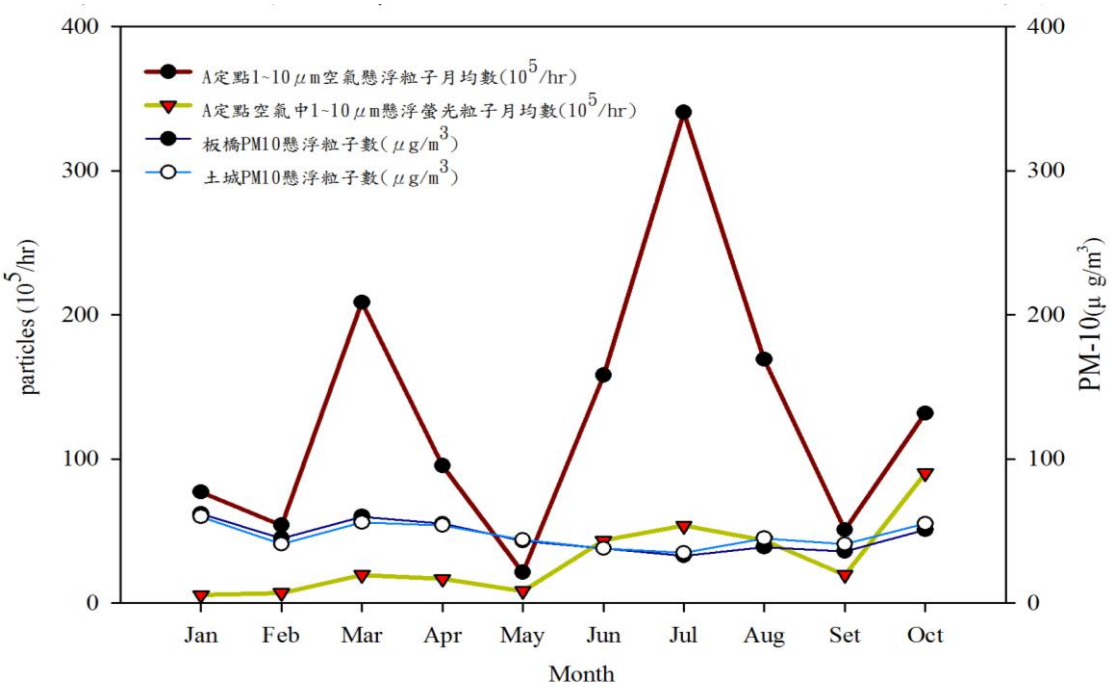


圖6、本計畫期間於 A 定點收集之空氣懸浮粒子及即時監測當中螢光粒子結果對照於觀測站 PM10 月平均數變化之趨勢圖

四、空氣樣本中螢光懸浮粒子即時變化與氣候變項之趨勢對照

由上述結果加入即時螢光懸浮粒子偵測之空氣樣本分析資料，因可藉由螢光訊號之即時監測，初步判斷可能為生物性之懸浮顆粒達到預警效果。相較於 XMX 之單一空氣採樣功能，FLAPS 更適於監測空氣中生物背景值之採樣。由於目前尚無空氣背景中 1~10μm 螢光懸浮粒子與各氣候變項之參考資訊，故本研究中亦觀察 1~10μm 螢光懸浮粒子與氣候變項間之關係，據以建立背景資料庫。本項次中所列之溫度、相對濕度、雨量與風速等變項資訊均節錄自中央氣象局氣候資料庫之 103 年度台北及板橋氣象觀測站紀錄數據，據以進行統計繪圖，用以對照於 1~10μm 螢光懸浮粒子月平均數進行觀察，並分別依蒐集數據趨勢變化進行比較，結果如圖 7~圖 10。(註:氣象觀測紀錄選取最近三峽地區之板橋觀測站為主，台北站為對照。)

(一)計畫期間定點收集之空氣中螢光懸浮粒子變化與溫度變化之趨勢比較

圖 7 中，X 軸數值為月份,左側 Y 軸為本計畫定點 A 收集之空氣粒子月均量(計量單位: 10^5/hr)，右側 Y 軸為觀測站量測之平均溫度(計量單位: ℃)。由圖 7 中觀察每月螢光懸浮粒子數變化與兩氣象觀測站記錄之月均溫度變化可見，103 年度 1~10 月間板橋與台北觀測站溫度變化幾乎一致，2 月後隨著溫度上升螢光懸浮粒子數增加，至 7~8 月為年度最高均溫，螢光懸浮粒子數亦增加至高點，之後隨溫度遞減而粒子數呈現下降，唯 10 月份螢光粒子數大幅上升，推測係與其他氣候因素相關。

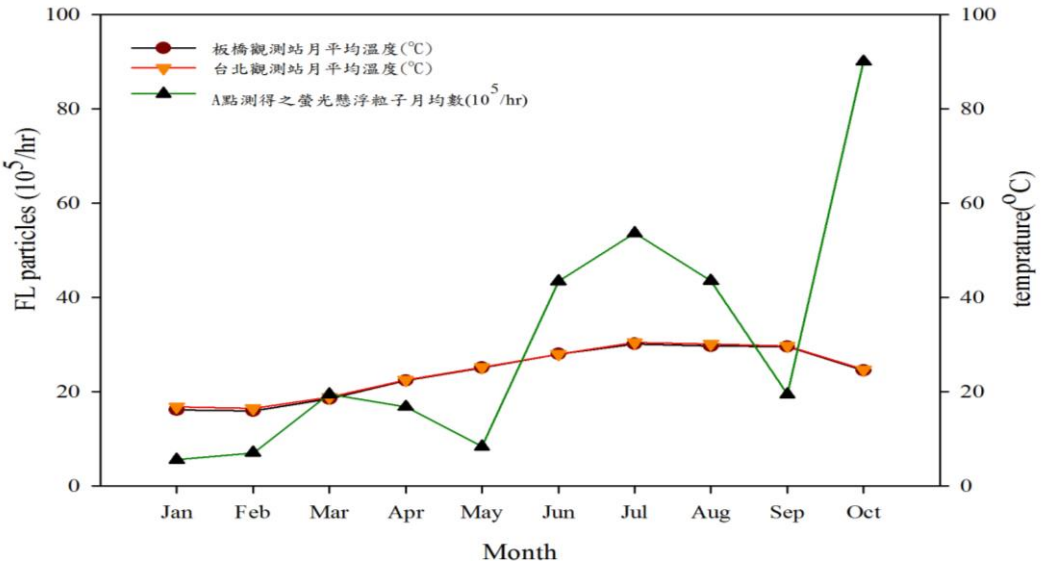


圖7、103 年 1~10 月間定點測得之螢光懸浮粒子變化與定點鄰近地區溫度變化趨勢比較

(二)計畫期間定點收集之空氣中螢光懸浮粒子變化與相對濕度變化之趨勢比較

圖 8 中,X 軸數值為月份,左側 Y 軸為本計畫定點 A 收集之空氣粒子月均量(計量單位: 10^5/hr)，右側 Y 軸為觀測站量測之相對溼度(計量單位: %)。由圖中折線趨勢觀察每月螢光懸浮粒子數變化與兩氣象觀測站記錄之相對濕度變化，其中 103 年度 1~10 月間板橋與台北觀測站相對濕度變化於 3、8、10 月略有差異，故本計畫定點區域係依地理位置參考板橋觀測站資訊為主，臺北觀測站資訊為對照，以圖 8 中 2、5、9 月之螢光懸浮粒子數均隨著相對濕度上升而下降，而 3、7、10 月之螢光懸浮粒子數均隨著相對濕度下降而略增加，顯見相對濕度與螢光懸浮粒子間具有對應關係。

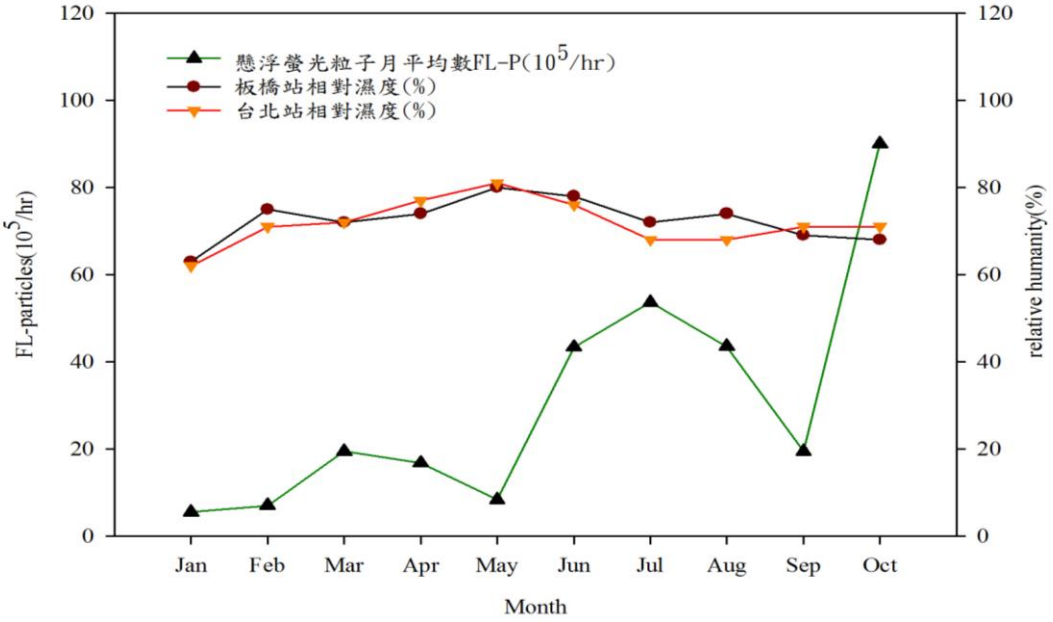


圖8、103 年 1~10 月間定點測得之螢光懸浮粒子變化與定點鄰近地區相對濕度變化趨勢比較

(三)計畫期間定點收集之空氣中螢光懸浮粒子變化與平均雨量變化之趨勢比較

圖 9 中,X 軸數值為月份,左側 Y 軸為本計畫定點 A 收集之空氣粒子月均量(計量單位: 10^5/hr),右側 Y 軸為觀測站量測記錄之降雨量(計量單位: mm)。由圖中折線趨勢觀察每月螢光懸浮粒子數變化與兩氣象觀測站記錄之平均雨量變化，其中 103 年度 1~10 月間板橋與台北觀測站區域平均雨量變化相近，本計畫定點區域係依地理位置參考板橋觀測站資訊為主，臺北觀測站資訊為對照，以圖 9 中 2、5、9 月之螢光懸浮粒子數均隨著平均雨量增加而減少，而 3~4、7~8、10 月之螢光懸浮粒子數均隨著平均雨量減少而增加，顯見平均雨量與螢光懸浮粒子間具有對應關係。

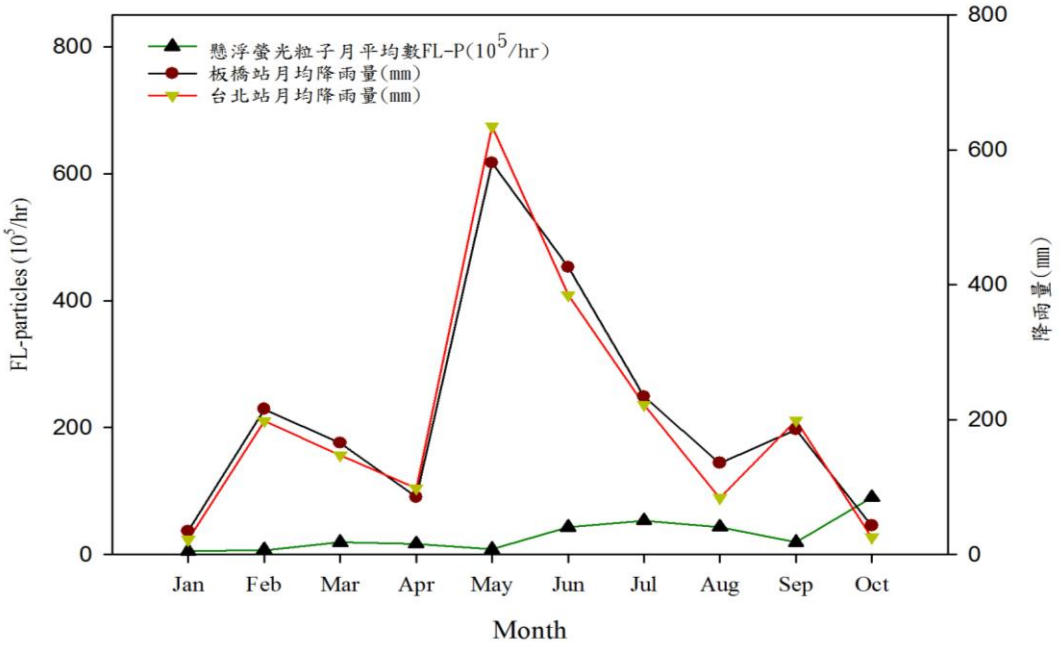


圖9、103 年 1~10 月間定點測得之螢光懸浮粒子變化與定點鄰近區域平均降雨量變化趨勢比較

(四)計畫期間定點收集之空氣中螢光懸浮粒子變化與風速變化之趨勢比較

圖 10 中，X 軸數值為月份，左側 Y 軸為本計畫定點 A 收集之空氣粒子月均量(計量單位: 10^5/hr)，右側 Y 軸為觀測站量測記錄之風速(計量單位: m/sec)。由圖中折線趨勢觀察每月螢光懸浮粒子數變化與兩氣象觀測站記錄之平均風速變化，其中 103 年度 1~10 月間板橋與台北觀測站區域於 4、7、9 月趨勢略有差異，本計畫定點區域係依地理位置參考板橋觀測站資訊為主，臺北觀測站資訊為對照，圖 10 中 3~4、6~8 月之螢光懸浮粒子數均隨著平均風速上升而增加，而 5 月份平均風速接近 3、7 月，然螢光懸浮粒子數反之下降，推測係因 5 月份平均雨量增加，相對溼度上升所致，故螢光懸浮粒子與風速之對應關係，或尚須納入雨量與濕度等因素考量為準。

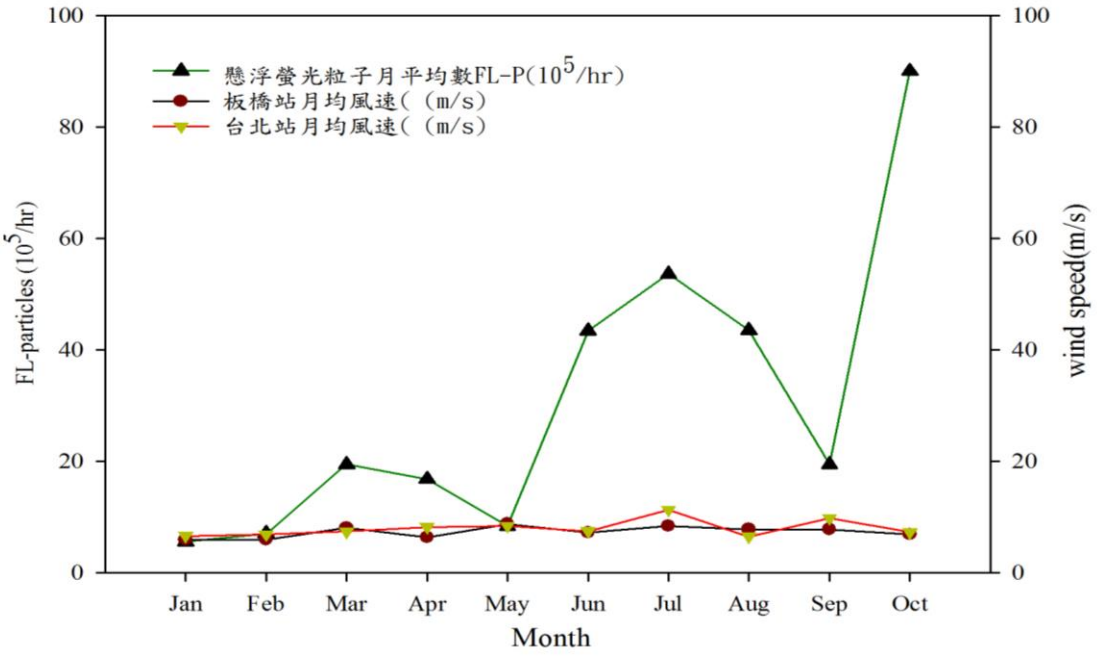


圖10、103 年 1~10 月間定點測得之螢光懸浮粒子變化與定點鄰近區域之風速變化趨勢比較

五、本計畫空氣樣本採集及菌落培養分析記錄

本計畫中執行期程為自 103 年 4 月中旬至 11 月中旬，每月以 XMX 空氣採樣器收取樣本，每次 40 分鐘收集於 5ml 無菌純水，並取 0.1ml 塗盤培養，收樣地點為本單位內採樣定點，表列僅以編號 A、B、C 點代表，並記錄各點採樣時間，天氣、溫度、相對濕度、定時收樣之空氣粒子均數、ATP 冷光讀值及不同條件下培養基培養之菌落數等參數，以提供後續定序結果之對照與微生物初步分析。另配合結案報告繳交時程，本表最後一次收樣培養記錄為 10 月，表列共計 7 個樣，完整記錄如表 4。

表4、本計畫期間於各定點之空氣樣本採集、相關氣候因子及菌落培養結果記錄

樣本編號 (備註 1)	採樣時間點	採樣地點 (備註 2)	天氣	溫度 (℃)	相對濕度 (%)	Royco 氣粒計數器收集之空氣懸浮粒子平均數(aver. particles/30s)	ATP 冷光讀值 (備註 3)	各取 0.1ml 培養之菌落數(CFU/ml)					
								Nutrient Agar (37℃, 48 小時)		Nutrient Agar (25℃, 48 小時)		Blood Agar Plate (37℃, 5% CO_2, 48 小時)	
								細 菌	真 菌	細 菌	真 菌	細 菌	真 菌
1	13:30	A 點 (建築 A 前方空地)	陰	23	68	52,519	29	2,135	10	2,830	540	1,745	45
	14:30	B 點(建築 B 前方空地)	陰	24	69	14,597	16	50	465	50	495	130	35
	14:42	C 點(林蔭步道空地)	陰	24	71	18,425	22	125	455	115	1,080	65	100
2	08:50	A 點 (建築 A 前方空地)	多雲	31	64	57,633	164	3,370	205	2,210	3,265	1,930	45
	09:15	B 點(建築 B 前方空地)	多雲	33	59	71,708	223	1,745	20	2,150	585	630	20
	09:30	C 點(林蔭步道空地)	多雲	33	60	70,161	109	175	40	160	430	85	15

樣本編號 (備註 1)	採樣時間點	採樣地點 (備註 2)	天氣	溫度 (℃)	相對濕度 (%)	Royco 氣粒計數器收集之空氣懸浮粒子平均數(aver. particles/30s)	ATP 冷光讀值 (備註 3)	各取 0.1ml 培養之菌落數(CFU/ml)					
								Nutrient Agar (37℃, 48 小時)		Nutrient Agar (25℃, 48 小時)		Blood Agar Plate (37℃, 5% CO_2, 48 小時)	
								細 菌	真 菌	細 菌	真 菌	細 菌	真 菌
3	11:00	A點 (建築A前方空地)	晴	40	45	12,867	195	0	300	0	3,310	90	290
	10:14	B點(建築B前方空地)	晴	32	61	16,371	178	0	10	0	50	5	5
	10:43	C點(林蔭步道空地)	晴	35	57	10,445	405	5	5	5	40	5	5
4	10:00	A點 (建築A前方空地)	晴	37	51	60,167	84	120	30	75	85	135	20
	09:20	B點(建築B前方空地)	晴	30	69	39,448	173	4,570	65	4,770	260	3,760	50
	09:40	C點(林蔭步道空地)	晴	36	58	28,631	72	470	75	640	220	265	15
5	09:55	A點 (建築A前方空地)	晴	33	70	44,299	194	80	5	75	225	35	35
	09:25	B點(建築B前方空地)	晴	32	61	23,109	173	440	315	620	480	500	110
	09:40	C點(林蔭步道空地)	晴	34	74	25,662	92	105	120	0	305	0	80

樣本編號 (備註 1)	採樣時間點	採樣地點 (備註 2)	天氣	溫度 (℃)	相對濕度 (%)	Royco 氣粒計數器收集之空氣懸浮粒子平均數(aver. particles/30s)	ATP 冷光讀值 (備註 3)	各取 0.1ml 培養之菌落數(CFU/ml)					
								Nutrient Agar (37℃, 48 小時)		Nutrient Agar (25℃, 48 小時)		Blood Agar Plate (37℃, 5% CO_2, 48 小時)	
								細 菌	真 菌	細 菌	真 菌	細 菌	真 菌
6	13:50	A 點 (建築 A 前方空地)	陰	24	66	29,505	198	2,390	0	264	165	2,885	5
	14:15	B 點(建築 B 前方空地)	陰	27	64	27,180	156	3,705	50	3,600	120	3,115	15
	14:30	C 點(林蔭步道空地)	陰	27	64	28,494	54	70	65	495	190	300	10
7	09:40	A 點 (建築 A 前方空地)	陰	28	56	23,213	74	6,250	35	12,750	140	5,100	25
	09:05	B 點(建築 B 前方空地)	陰	28	67	27,665	41	85	25	50	100	15	0
	09:25	C 點(林蔭步道空地)	陰	29	58	25,244	86	11,100	20	17,250	90	4,700	10

備註

1. 本計畫期程雖自 103 年 4 月 16 日至 12 月 31 日止，本表列記錄配合 11 月中旬結案報告繳交，僅收集 7 組樣本及培養，記錄 4~10 月期間採樣記錄(每月採樣乙次，共計 7 次並予樣本編號)，培養結果係由每次採集後液化之空氣檢體 5ml 各取 0.1ml，三區塗劃於 2 個 Nutrient Agar(分別於 37℃及 25℃培養)與 1 個 Blood Agar Plate(37℃, 5% CO_2)各培養 48 小時後觀察其總菌落數。
2. 本計畫為方法建立之前測試研究，故採樣地點固定於三個定點位置執行，以利每次採樣後之數據分析之一致性，為重要之參考依據，在本表欄位中僅以 A, B, C 點代碼表示。
3. 所有存活生物體內都含有三磷酸腺苷(adenosine triphosphate, ATP)，微生物亦不例外，所以檢測環境採集標本之 ATP 含量，可間接驗證當中具有生物體或微生物。故採樣後之液化檢體同時進行塗盤培養，並以 EAI 公司購入之 BioHAZ Kit 與手持式 ATP 冷光檢測儀(ATP luminescence detection instrument, model 4700. New Horizons Diagnostics)進行樣本 ATP 測試，以證實樣本當中存在生物性物質。

六、NGS 定序前之核酸濃度測試結果

NGS metagenomics 於 Illumina Miseq 上機定序之 genomic DNA 建議濃度需大於 50ng/ml(或重量大於 0.8μg)。故由上述樣本中選取 8 管各收取 40 分鐘之空氣樣本(樣品編號 1~8),先以材料與方法之前處理步驟及醋酸氨法進行核酸純化後,使管底核酸 pellet 完全乾燥後，以 30 μl TE Buffer 回溶，取 5 μl TE Buffer 混合核酸染劑後，於 1%膠體電泳觀察核酸原始片段大小與分布，並無任何訊號。再應用 Qubit fluorometer 2.0 進行核酸濃度定量，初步使用 DNA HS 套組進行核酸濃度測試，以利後續序列庫創建(library construction)、放大子(amplicon)與定序。測試結果，在樣本未稀釋下檢測，編號 1~5 管為無濃度訊號，編號 6~8 濃度亦極低，分別為 0.502 ng/μL、0.196 ng/μL、0.134 ng/μL，並無法進行後續定序。

表5、萃取之核酸回溶後直接進行膠體電泳之樣本濃度紀錄與結果

Lane No.	Sample Name	Dilution Ratio(×)	Test Volume(μL)	Sample Integrity
M1	λ-Hind III digest(Takara)	1	3	N
1	Sample-1	1	5	N
2	Sample-2	1	5	N
3	Sample-3	1	5	N
4	Sample-4	1	5	N
5	Sample-5	1	5	N
6	Sample-6	1	5	N
7	Sample-7	1	5	N
8	Sample-8	1	5	N
M2	D2000 (Tiangen)	1	6	N

Condition of gel electrophoresis:
concentration of agarose gel: 1 %; voltage: 150 V; electrophoresis time: 40 min

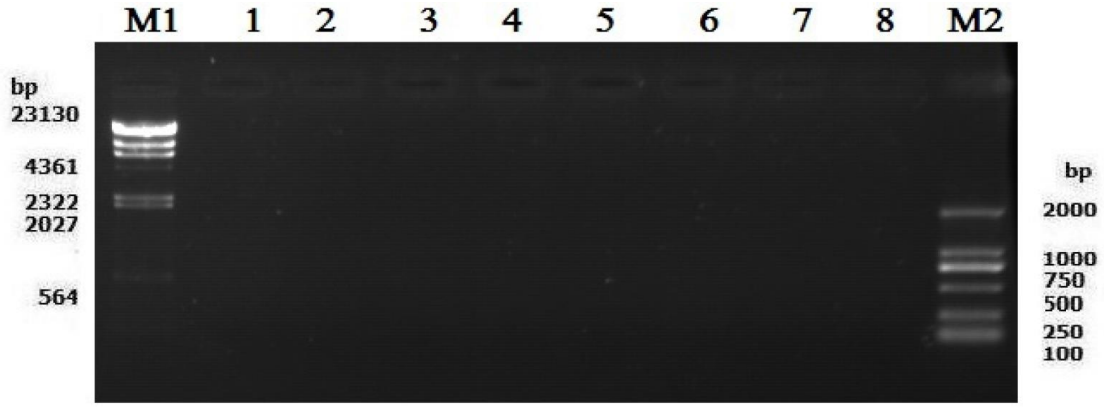


表6、8 個樣本萃取之核酸濃度以 Qubit fluorometer 測定結果

Sample	Test Instrument	Test Kit	Dilution Ratio (×)	Test Volume (μL)	Total Mass (μg)	Concentration of test sample (ng/μL)
1	Qubit	DNA HS	1	1	0	0
2	Qubit	DNA HS	1	1	0	0
3	Qubit	DNA HS	1	1	0	0
4	Qubit	DNA HS	1	1	0	0
5	Qubit	DNA HS	1	1	0	0
6	Qubit	DNA HS	1	1	0.01	0.502
7	Qubit	DNA HS	1	1	0	0.196
8	Qubit	DNA HS	1	1	0	0.134

肆、討論

本年度計畫已完成之成果，包含空氣採集方法之建立、採樣時間最佳化、空氣樣本中微量之生物物質核酸萃取技術建立，及藉樣本之培養分析初步確認空氣樣本中具細菌與真菌等，然而最終擬運用次世代基因定序技術於分析空氣樣本中之菌相，目前仍有樣本總核酸濃度不足之窒礙問題待解決，並已重新送檢進行分析中。然而，上述結果中關鍵性之決定因素仍在於第一階段--空氣樣本採樣與品質之良窳，不僅檢體收集量要夠大，檢體中之生物性物質的含量亦決定後續檢測分析之成敗。故本節將就結果中之樣本收集效率、樣本核酸濃度與核酸純化方法之差異、螢光懸浮粒子受氣候因子之影響與建置預警能量之參考等部分提出討論。

一、空氣樣本收集效率、樣本核酸濃度與核酸純化方法之差異

就空氣檢體收集的體積與收集效率上，本計畫採用之 XMX 2A/2AL 高通量空氣濃縮液化收集器已為目前國內可獲得之空氣採樣儀器中最佳機型，其收集濃縮空氣之效率每分鐘最高可達 600~800 公升，為許多相關文獻所採用。然執行中發現此機型僅具備大量收集空氣之基本功能，並無法計數空氣懸浮粒子數量、粒徑分佈，尚須仰賴空氣粒子計數器同時收集，並建立轉換公式以利後續資訊分析。除收集檢體相當耗時且無法確認當中之生物性顆粒比例含量，就實際應用層面而言效率不佳。故另規劃導入一具有偵測螢光粒子之動力分析裝置(Fluorescence Aerosol Particle Sensor, FLAPS)，其主要核心功能為快速、大量抽取偵測空間範圍之空氣懸浮粒子，並以兩道雷射光源區辨顆粒之粒徑大小及是否具生物性螢光，並計算粒徑分佈與總數量俾以進行分析，可快速區辨可能之生物性氣粒污染，同時亦可短時間內大量濃縮(600~800 公升/分鐘)液化收集可能具生物活性之空氣懸浮粒子，予後方實驗室確認空氣是否確遭生物危害性之懸浮粒子污染，進而達成早期偵測之目標，係為生物危害事件時重要之預警工具。基於生物戰劑或生物疫病致病原多具有高危害、感染潛伏期及高擴散性等特點，因此早期預警可有效應用生物戰之戰場指揮與生物事故現場，降低人員感染風險，是以上述早期預警系統便成為反制生物性致病原威脅之關鍵防禦能量。此外，就空氣中生物性有害物質之採樣效率而言，在無法初步預測何區段為生物性空氣懸浮粒子時，僅能以長時間收集大通量之樣本試圖取得當中有限之生物性物質進行後續分析，耗時且耗能，若能以生物性懸浮粒子預警方式採區段性聚焦之樣本收集，無論於後續核酸純化或樣本體積都能有效控制，分析始具意義。

就本計畫收集之空氣樣本純化核酸後進行原始濃度之電泳結果，如表 6 之電泳圖與表 7，單管連續收集 40 分鐘之空氣樣本核酸原始濃度之電泳結果並無訊號，以 Qubit 確認核酸濃度，8 管中僅 3 管可測得濃度，但均低於 1ng/μL，推測可能原因有二：(一)空氣背景樣本中原有之生物物質(如細菌、真菌)等濃度即極低，是以本計畫所預劃收集之空氣總量不足狀況下，由於這些樣本中之生物物質未經訊號放大程序(如瓊脂培養)，故直接純化並無法得到足量之核酸。(二)核酸純化過程之誤差，致原本已微量之檢體經純化過程損失或純化效率差，所以濃度低無法測得。針對上述原因之改善方式，係以延長 DYCOR 原廠建議之空氣採樣時間以求增加樣本濃縮體積，並同時進行培養基養菌達到前端放大目的，另 PCR 反應擴增核酸達到後端放大目的以同時確認可能之原因。以圖 4 中各不同採樣時間點純化之核酸於 16S 引子之 PCR 放大 30~35 個循環後，30-40 分鐘收集之樣本(空氣收集總體積約 24,000-32,000 公升)可於膠體電泳觀察到產物訊號，此與本計畫原本規劃僅估算僅收集 10 分鐘之空氣體積(空氣收集總體積約 6,000-8,000 公升)已有 4 倍落差，且如表 6、7 之結果，初次以此單管檢體送次世代基因定序，第一階段即確認原始樣本核酸濃度不足(NGS 上機濃度需大於 50ng/μL)，經估算依現有濃度則需收取 8~10 管連續收取 40 分鐘之空氣檢體純化之核酸始可滿足一次 NGS 定序需量，是以重新採樣及純化核酸，並聚集 8 管核酸量(此預估空氣總量體積約每分鐘 320,000 公升，為原估算 10 分鐘採樣之約 40 倍量)，已於 11 月中旬送件重啟定序。另由表 5 之培養結果中，可發現無論細菌或真菌，經由 48 小時適當條件培養後之菌落數最高僅約 10^4 CFU/ml，有時甚至為零，相較於正常 16~18 小時可達 10^8~10^9 CFU/ml 之培養效率。推測應為樣本之原始菌數少，顯見在戶外高通量之濃縮空氣中背景中存在之細菌、真菌濃度仍極低，正常之人體活動呼吸應不致遭受影響。目前解決之方法為延長採樣時間或連續收取多組樣本後聚集為一個樣本後檢送定序。

此外，圖 4 結果中同為採樣 40 分種樣本以不同核酸純化方式進行 PCR 後之電泳結果差異，推測因本次採用之核酸純化套組是以微量管柱濾膜(column & filter membrane)型式進行核酸反覆沖提達到純化目的，而原本即微量樣本純化之核酸可能黏附於濾膜，導致核酸抽提效率更低，故 PCR 產物並不明顯。反之，改良之醋酸氨法因採用有機相分離蛋白質，並以酒精沉澱方式萃取核酸，所得到之核酸量較高，故與市售套組比較純化核酸效率較佳。

二、螢光懸浮粒子受氣候因子之影響

由於生物性懸浮粒子大多具有蛋白質外殼，於高能階光源激發時，可產生螢光訊號被偵測，而初步研判為生物性之懸浮微粒進行收集。而此類懸浮粒子之形成來源可能為花粉、孢子、細菌、病毒、真菌等，在粒徑 1~10μm 間之懸浮粒子易受諸多氣候因子之影響，這部分也是預防與偵測重要之參考數據。在圖 6 中，收集空氣之 A 定點為林木較茂盛之室外空間，其無論是 1~10μm 之空氣粒子或當中即時測得之螢光懸浮微粒趨勢，於 3 月、7 月各顯示一粒子數量上升之波峰，然而在樣本進行培養基細菌或真菌培養之菌落形成數量並未特別增加，研判此類螢光粒子數多為懸浮花粉所致之偽陽性訊號，並非生物性危害因子，然而欲有效排除此類偽陽性之預警訊號，除需要有長期間收集之資訊，建立完整之背景與趨勢比對始能提供機器依可靠之基礎值，以利區辨生物性有害物質。然此項樣本收集作業需人力配合前端之樣本採檢操作、後續實驗室鑑定、培養及定序資料處理分析等工作，無法短期內一蹴可及。故此類計畫建議於方法建立之後，藉由實際操作驗證與修正，並建立背景資料庫，以供生物預警系統建置時之背景資訊可用。

另就結果三、四中，藉由輔以螢光粒子動力分析裝置(FLAPS)收集預警之 1~10μm 螢光微粒，可視為生物性物質之初步篩檢，故本計畫中觀察其粒子數量變化趨勢與氣候因子之關係，在圖 6~10 中，溫度變化對於空氣中之 1~10μm 螢光懸浮粒子數量影響甚微，反而是雨量、相對濕度與平均風速等三項因子影響明顯。推測可能原因在於當乾燥及風速兩項氣候因素同時作用時，空氣中懸浮粒子乾燥量輕易隨風速帶動，故粒子總數升高。而圖 9 之中 5~6 月為年度月平均雨量之最高點，雨量遽增，降雨夾帶著懸浮粒子落下且濕度上升，懸浮之空氣粒子因潮濕質重而沉降，不易隨風帶動，以致空氣中懸浮粒子與螢光粒子總數均下修，整體變化趨勢與雨量、相對溼度與風速相關。故歸納氣候因子對於 1~10μm 粒徑之懸浮粒子與當中螢光粒子在空氣中懸浮數量之消長，影響程度分別是：雨量>相對濕度>平均風速度>溫度。

三、建置生物預警能量之參考

欲判定空氣遭受生物性危害懸浮粒子污染，係以一時間點所測得之生物性懸浮粒子濃度相較於平時監測之空氣背景值據以判定，而背景值可能因氣候條件與季節變化而變動，故較長時間區段之例行監測及分析據以瞭解空氣中懸浮粒子組成與分佈，為重要之基礎知識。具備此資料訊息，始能於其組成改變時快速分析研判達到預警偵測之目的。

本計畫為國內首次應用上述螢光粒子之動力分析裝置(FLAPS)進行空氣中背景資訊收集與分析，經測試確實可達到預警生物性懸浮粒子之偵測目標，效率符合本計畫最終目標，建置生物預警系統之前導評估。然而此類機種或為國家安全層級之現役防禦能量，或因國內相關需求與市場規模限縮，國內大多未引進，本文中僅簡略介紹國內、外現有與發展中之能量，並將已蒐集之各廠牌儀器相關資訊檢附於附錄，俾提供相關主管機關後續採購建置之評估與參考。

(一) 國內現有機型與能量

1. 加拿大Dycor之XMX空氣微粒濃縮收集器/FLAPS螢光粒子之動力分析裝置(邁帥生物科技公司代理)

   本計畫中所採用之XMX/2ML高通量機型系列是由加拿大之DYCOR公司生產(如圖11)，國內代理商為邁帥生物科技公司，該機型特點為高通量收集空氣，以每分鐘約600-800公升收集量(可手動調整)，濃縮於收集管之液體中，以利後續分析，此機型為目前本單位與疾病管制署使用中，其性能均較為熟悉，本文不另詳述。唯本計畫中所引用之螢光粒子之動力分析裝置，為TSI公司生產之固定式機型，目前DYCOR公司已整合為可攜式FLAPS裝置(如圖12)，如前所述此藉由雷射光源區辨顆粒之粒徑大小及是否具生物性螢光,並計算粒徑分佈與總數量以進行分析，可快速區辨可能之生物性氣粒，為結合XMX功能之高效能生物預警系統，為國內現行結合生物預警功能之唯一機型，缺點為價格昂貴，且因為美軍現役裝備，仍受美國進出口管制。DYCOR機型相關性能資訊與國內代理商資訊詳如附錄一。

圖11、加拿大DYCOR公司生產之XMX/2ML空氣微粒濃縮收集器

圖12、DYCOR整合由TSI公司生產之可攜式生物預警系統-螢光空氣懸浮粒子感測器(FLAPS)

2. 法國Bertin之Coriolis® Recon氣膠微粒採樣系統(科安企業公司代理)

Coriolis® Recon是法國CEA與Bertin公司共同發展完成之一系列氣膠微粒採樣儀器，原國防發展計畫代號為Célia & KIM，完成開發後技轉至民間廠商Bertin量產販售，國內由科安企業公司代理進口，其生產之Coriolis® Recon型號包含三型: μ、FR及MS系列(如圖13)，差異在於收集之進氣效率不同，其原理為利用其專利之氣旋式液體採集技術(wet cyclone)將吸入之空氣粒子直接打入前端收集瓶(15-20 ml)中，在收集瓶中亦形成漩渦，一方面避免危害粒子飛揚，另一方面可藉離心力將這些粒子集中於瓶底(原理圖示如下圖14)，此與本所現行之XMX之乾式抽吸空氣後，濃縮注入緩衝液方式略有不同，然目的相同。此儀器優點是因此系統原本發展於野外使用，故除設計可拆解便於攜行外，μ、FR系列尚可選擇以內建電池充電使用或外接交流電源使用，對於此類功率耗損較高收集器是少見之設計，μ系列電池使用時間約2小時，FR系列效能較高，電池使用時間約1小時；充電設計機型之收集效率μ系列僅300 L/min，為XMX之一半，但仍優

於International Research公司開發之SASS 2300系列等空氣採樣系統(如圖14)；而FR系列收集效率約600 L/min與XMX相當，另MS型氣流抽吸效能更稍高，可達630 L/min，此即與本計畫使用之XMX空氣採樣機650~850 L/min相近。前述之Célia即是此氣膠微粒收集器，KIM系統是利用免疫磁珠原理進行空氣樣本檢測，然後者檢測能量並未輸入國內，使其功能性僅止於氣膠微粒之收集，是較為可惜之處。目前國內並不清楚使否有使用此儀器之單位，故其實用性與效能尚待測試確認。Bertin Coriolis® Recon儀器性能相關資料及國內代理商科安公司資訊，詳如附錄二。

圖13、科安公司所引進之Bertin Recon系列氣膠微粒收集器

左圖為μ系列，右上圖為FR系列，右下圖為MS系列

圖14、法國Bertin之Coriolis® Recon氣膠微粒收集器及其wet cyclone原理

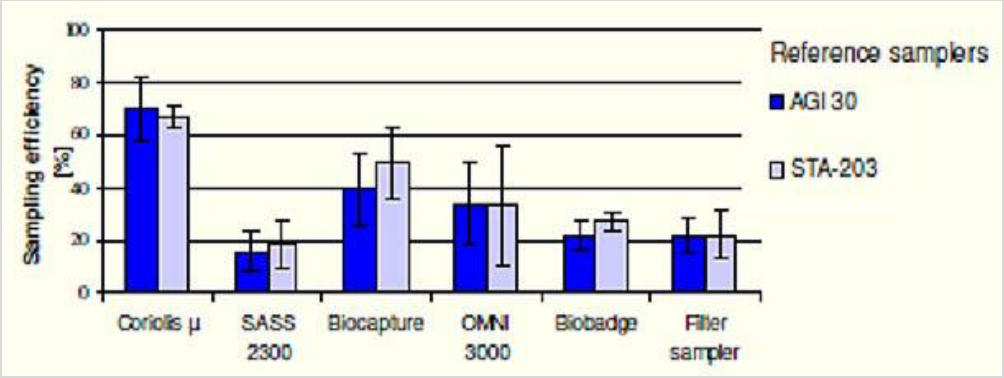


圖15、Coriolis® Recon系列與其他功能相近儀器之採樣效率比較(圖片來源：科安企業公司)

3. SKC之BioStage衝擊板式生物氣膠採樣器(科安企業公司代理)

此BioStage生物氣膠採樣器(如圖15)是依據Andersen N6生物氣膠採樣器(如圖16)改良製造，由三個金屬鋁製組件製成，包含防鏽、抗氧化材質之進氣圓孔(Cone)、衝擊板與底盤，以SKC將Anderson N6之彈簧夾固定改為SureLock之螺紋旋緊方式避免漏氣，可維持樣本之完整性，易於流量校正、安裝與滅菌。其運用慣性衝擊原理，衝擊板上具400或200個精細的0.25㎜小孔，空氣氣流通過衝擊板小孔後，由100×15㎜的瓊脂培養皿捕集。針對ACGIH(American Conference of Governmental Industrial Hygienists)所建議的採樣方法所設計，符合美國

NIOSH(National Institute for Occupational Safety and Health) 0800、0801方法，以及環檢所室內空氣總真菌(NIEA E401.11C)與總細菌(NIEA E301.11C)之檢測方法，適用於室內與戶外空氣中活體微生物的採樣。儀器性能相關資料詳如附錄三。

圖16、SKC改良之BioStage衝擊板式生物氣膠採樣器(圖片來源：科安企業公司)

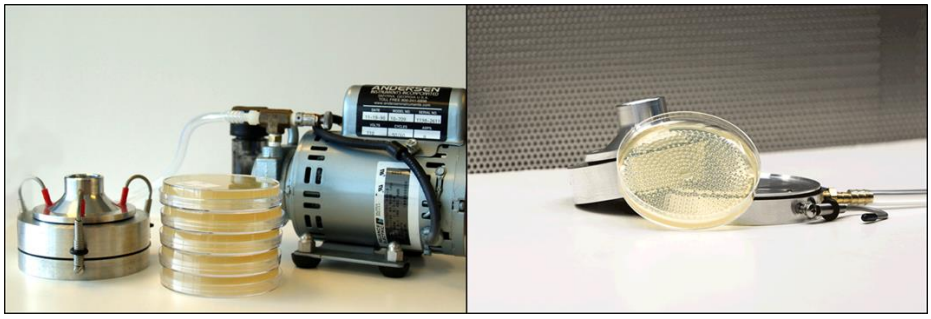


圖17、SKC BioStage生物氣膠採樣器

BioStage 是以左圖中之 Andersen N6 為樣本改良其彈簧夾式裝置，右圖為其衝擊板捕集培養基

(二) 國內未引進之機型與能量

1. 空氣微粒收集器：

此部分尚有產品技術已發展成熟但國內廠商未代理引進之儀器，例如美國Research International公司開發之SASS系列儀器，包含乾式、濕式收集等不同機型，如SASS 2300濕式空氣採樣器、SASS 2400低通量濕式空氣採樣器、SASS 3100乾濾式空氣採樣器、美國FLIR公司開發之手持式電池供電之FIDO B1/BioCapture 650乾式空氣採樣器等均僅具空氣粒子收集並無預警效果，且此上述款機型均可以電池供電，攜帶方便機動性強，缺點仍是在於其收集效率約

介於200~350L/min，僅為XMX之一半效能。若考量便利性，FLIR之FIDO B1/BioCapture 650乾式空氣採樣器為目前歐亞國家所採用，為可參考之選項。限於篇幅，本文內並未詳細介紹產品資訊，僅列於附錄供需求單位評估參考。Research International儀器及性能相關資料詳如附錄四，FLIR儀器及性能相關資料詳如附錄五。

圖18、Research International 之 SASS 2300 及 FLIR 之 B1/ BioCapture 650

上圖左為美國 Research International 公司發展之 SASS 2300 濕式空氣粒子收集器，上圖右為美國 FLIR 公司發展之 FIDO B1/ BioCapture 650 手持式乾式空氣微粒收集器，上述兩機型均可藉電池供電使用

2. 生物性氣膠即時預警系統：

生物預警系統部分需同時具備空氣採集及生物性預警能量，此類儀器尚有美國Research International公司開發之BioHawk八通道空氣採樣暨生物偵測器、美國FLIR公司發展之FIDO B2\IBAC生物威脅即時警示系統、法國Proengin公司之MAB野戰型生物性空氣粒子監測警示系統等，FIDO B2本身建置IBAC技術具有生物預警功能，而Proengin MAB則是規畫結合前述之法國Bertin公司之Célia & KIM兩儀器，形成預警(前)、高通量收集(中)、偵測確認(後)之完整防禦構想，為具前瞻性之發展。然而縱使上述儀器性能均標榜偵測快速、專一且偵測靈敏度高，然而缺點同前述，其空氣採集效率皆於200~350L/min，若低生物粒子濃度或樣本量不足導致未檢測出之偽陰性結果，或無法即時、有效研判現場之生物危害狀況。然上述儀器均為目前偵測性能水準以上之現役裝備，故仍具參考價值。Research International儀器及性能相關資料詳如附錄四，FLIR儀器及性能相關資料詳如附錄五，Proengin儀器及性能相關資料詳如附錄六。

圖19、BioHawk 生物偵測器及 MAB 野戰型生物性空氣粒子監測警示系統

上圖左為美國 Research International 公司開發之 BioHawk 八通道空氣採樣暨生物偵測器，圖右為法國 Proengin 公司發展之 MAB 野戰型生物性空氣粒子監測警示系統

圖20、美國 FLIR 公司開發之生物預警系統

上左圖為 FIDO B2 具 IBAC 技術之生物氣膠偵測暨收集機型，右圖為 FIDO B2 生物氣膠即時監控機型

(三) 國外發展中之大型生物預警系統

歐盟發展之兩階段生物防護預警系統-TWOBIAS：有鑒於生物性攻擊於各大公共據點之可能威脅，歐盟亟欲發展生物預警系統，這種作法雖類似仿效美國全國重要據點建置之定點式氣膠收集預警器，但歐盟捨棄採用定點模式之架構，而是希

望得到一可確效、模組化、貼近市場需求且低誤報、可移動之整合式生物預警系統。故於第七期科研架構計畫(European Seventh Framework Programme, FP7)中挹注總預算約為505億歐元之研發經費，廣徵研發與整合全新系統，希望藉此機會自主培植與建置可讓人民信賴生物防禦能量。由於2013年是七期架構計畫的最後一年，此欲建置於全歐洲公共據點之生物預警系統，名為「快速偵測空氣傳播病原威脅之兩階段生物性監控預警系統」（Two Stage Rapid Biological Surveillance and Alarm System for Airborne Pathogenic Threats）已發展完成，並於測試中。其區分兩個階段發佈警示，藉由儀器收集氣膠之空氣粒子收集檢測是否為生物性威脅與分析辨識威脅，並回傳資訊予令控中樞，記錄、整合這些資訊，預計可於威脅發生後一小時內確認是否為生物攻擊、病原為何，發展代號為TWOBIAS，整體發展之應用構想與原理架構如圖21，是以短時間連續區段收集的方式，氣流第一時間經過空氣收集器(此階段採用的是上述SASS2300空氣粒子收集器)被吸入偵測，當紅外線偵測到2~10μm之粒子可能為陽性時，啟動第一階段警示，此起動訊息即予令控中樞，此階段為空氣粒子之生物性檢測(biological detection unit, BDU)，目的為檢測以預警(detect-to-warn)，此同時啟動分析儀大量收集空氣樣本並進行分析確認威脅，若確認是某生物性病原，則啟動第二階段預警，若僅為誤報則不啟動第二階段預警，這一階段目的為檢測俾以應變處置(detect-to-treat)，無論啟動與否判斷訊息都會回到令控中樞，進行記錄、監控及彙整，偵測至確認全程可於一小時內完成。故第二階段之檢測分析儀器不僅快速且要兼具靈敏度與專一性，此部分之儀器發展值得後續追蹤。

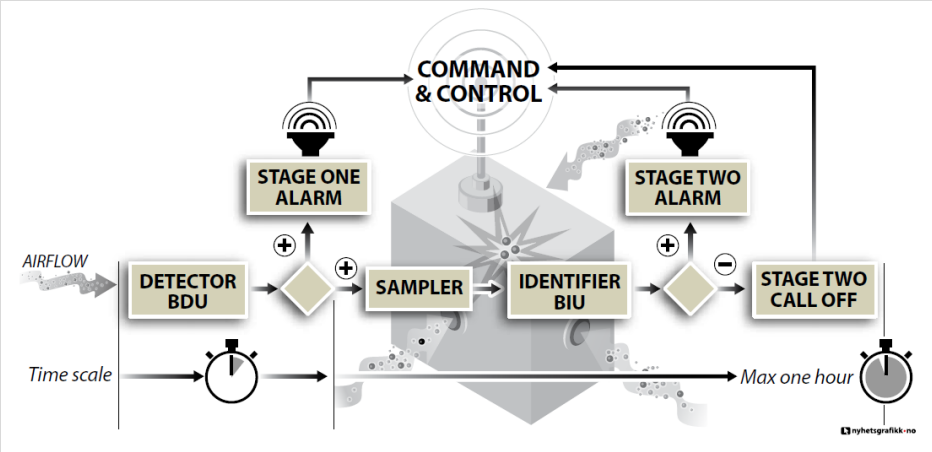


圖21、歐盟發展 TWOBIAS 之應用構想與原理架構圖示

陸、重要研究成果及具體建議

1.本研究計畫之成果與發現

(一)本計畫應用 XMX 空氣採樣模組收集定點之空氣懸浮微粒樣本分析，並測試輔以螢光雷射動力氣粒分析系統(FLAPS)，確可分辨粒徑 1~10μm 間之螢光懸浮微粒，達到生物預警目標。

(二)由不同時間點之 PCR 結果，確認 30-40 分鐘之樣本濃度為 PCR 檢測之最佳時間條件。

(三)本計畫所建立之醋酸銨核酸純化法應用於空氣檢體核酸萃取，於實驗結果驗證可行且優於市售之核酸萃取套組。

(四)本計畫結合空氣粒子計數器同時測定採集點之空氣粒子數值，建立 XMX 收樣體積換算空氣粒子數之推估算式。

(五)根據測得之螢光懸浮粒子變化相較於溫、濕度與風速等相關氣候因子，結果呈現與濕度、雨量及風速具相關性，為重要之參考資訊。

2.計畫對民眾具教育宣導之成果

(一)在本研究計畫中以高通量空氣採樣之培養結果或螢光粒子偵測結果發現，常態下空氣背景中之生物物質濃度極低，無論是細菌或是真菌皆然。雖然本研究尚未確認其中之菌種與數量，但就上述初步成果，仍可推估確認，在城市中以一般人體日常之呼吸量，並不至於吸入過多生物性危害物質，對於人體之危害性應大多是物理性及化學性物質造成，無須過度恐慌。

(二)就本計畫螢光粒子與氣候因子之影響分析中，可見雨量、相對濕度與風速為影響生物性空氣懸浮粒子之重要因素，故民眾於戶外活動時，尤其是山林區可能有較都市存在高量之生物性懸浮粒子，如花粉、孢子等，對人體可能有致過敏之情形，若要避免可選擇於降雨後、相對濕度高時進行活動，可降低吸入大量生物物質之機會。

3.計畫對醫藥衛生政策之具體建議

(一)由於生物性危害發生大多具潛伏期，無法立即由大量傷患產生進而防範，空氣中之生物危害尤然，僅藉片段性之空氣背景數值監控並無法有效防範生物性懸浮物質之危害真正發生，建議仍須考量建立定點、常態監測之生物性預警系統，補足現行之空氣監測缺口，以防範於未然。

(二)本計畫執行時程短，主要聚焦在建立無須培養、可直接分析空氣收集樣本中生物性物質(如細菌)之方法，冀藉由本方法之建立，持續應用於相關研究計畫與修正，除驗證方法可行，並進行條件最佳化，以評估應用於上述之生物預警系統。

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捌、附錄

附錄一、加拿大 Dycor 機型相關性能資訊與國內代理商資訊

(一) Dycor XMX/2L-MIL 空氣採樣器

XMX/2L-MIL Technical Data Sheet

This unit was designed and built in response to the need for a weatherproof, outdoor aerosol collector. It has been sold to various U.S. Air Force bases and other military and first responder organizations around the world.

The XMX/2L-MIL is an aerosol separator, sample preparation, and high mass flow concentrator system, design to operate under harsh field conditions. This system was designed to process and collect large concentrations of aerosols in the respirable range (1 to 10 microns in diameter) in relatively short periods of time, i.e., when the cloud is over the XMX. This system collects high volumes of air, strips away the large dust particles and the very small micro debris and concentrates the aerosols of interest. The particles are then impinged into a sample collection vial (centrifuge tube) containing customer specified liquid (normally type 1, sterile water or phosphate buffered saline). Once the sample is collected, the user removes the centrifuge tube for subsequent analysis (immuno-assay, PCR, culturing). One of the primary issues in bioaerosol detection is the fact that it is difficult to obtain enough sample of interest to detect an airborne threat concentration that is lethal to humans. Our system captures high concentrations of particles and prepares a small aqueous aliquot for analysis with minimal dilution.

- Recent advances in XMX capability have included third-party validation of exceptional collection efficiencies in the human respirable range, especially in the 2-5 micron range, as well as in capturing and maintaining viability of viral and bacterial particles in human and animal disease outbreaks (*contact Dycor for details*). Not only is the XMX suitable for industrial hygiene applications, as in PM-10 monitoring, but its practicality as a biosampler has now been field-proven as well.
- The XMX/2L-MIL is fully field-decontaminable.
- The XMX system is designed to operate under field conditions, while wearing MOPP gear. There is superior system reliability, with only two moving parts, to reduce maintenance and ensure a high MTBF. This feature minimizes operator effort to reduce the possibility of cross-contamination between collection missions.
- Dycor now supplies a **field validation kit**, allowing for confirmation of collection efficiencies and operator training in the field using a simple visual confirmation kit.
- For dry collection applications, the XMX comes with a dry filter unit option, which can replace the liquid vial. The particles, rather than impinging into water, are impacted onto

the dry filter which is then removed and dissolved in liquid for further analysis. Filter cartridges are COTS and are readily available.

- The XMX/2L-MIL is on the USAF Table of Allowances, with **National Stock Number 6665-01-509-9540**, Sampler Kit-Air, and is available through DLA via DSCP today.

Specifications

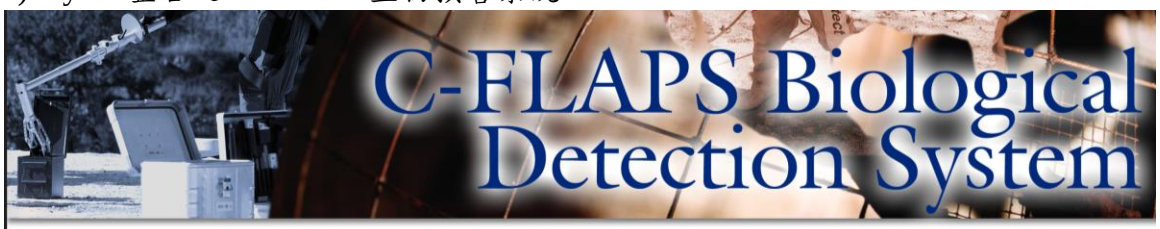
Dimensions	Width: 46 cm, Height: 58 cm (with stack), Depth: 33 cm
Weight	Approximately 17 kilograms
Power Requirements	110V AC or 220V AC
Power Consumption	10 A @ 110V AC, 5A @ 220V AC (optional)
Intake Flow Rate	530 Standard Litres/Minute (SLPM) +- 25 SLPM
Secondary Flow Rate	12 liters per minute
Particle Size Range	~ 1 – 10 microns
Operating Temperature Range	0 to +50°C
Decontamination Options (Application Dependent)	Air Purge – 5 minutes Bleach Paraformaldehyde VHP (Vaporous Hydrogen Peroxide)
Collection Vials	Fisher commercial-off-the-shelf 50ml centrifuge tube
Setup/Teardown Time	5 minutes
Collection Medium	Liquid – includes sterile water, PBS solution, surfactant solution OR Dry Filter – COTS filter
Collection Medium Volume	Fixed at approximately 5ml (liquid) ; minimizes dilution for integrated collection period
Ingress Protection (Environment)	Mil-Std 810F Rating
National Stock Number	6665-01-509-9540

For further information on the XMX/2L-MIL Collector or any other Dycor products, please contact:

Dycor Technologies Ltd.
1851 – 94 Street N.W.
Edmonton, AB Canada T6N 1E6

Tel: 780-486-0091
Fax: 780-486-3535
Toll Free: 800-663-9267
Email: sales@dycor.com

(二) Dycor 整合之 C-FLAPS 生物預警系統

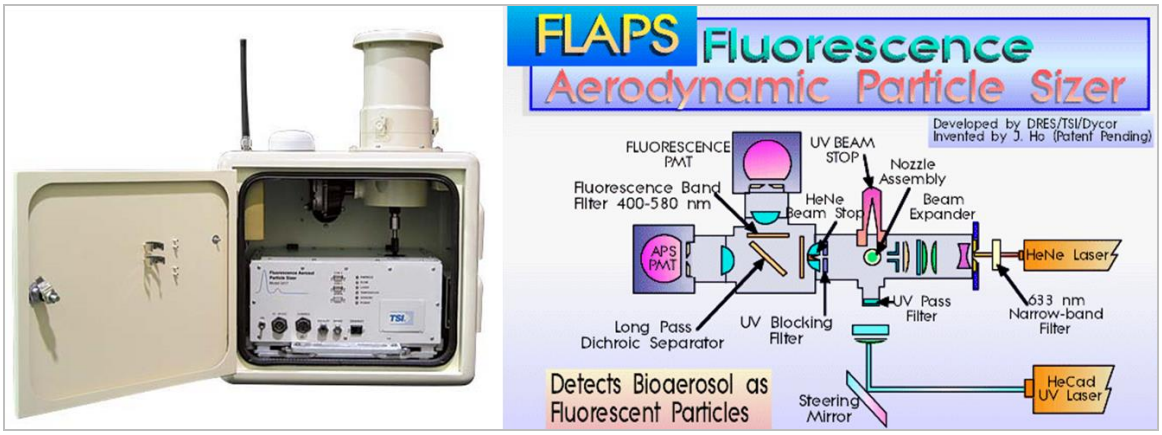


C-FLAPS is the latest biological detection system from a distinguished pedigree of ***proven, fielded and flexible solutions*** by the team of Dycor Technologies Ltd. and TSI Incorporated. It is an off-the-shelf system, deployed operationally with defense and research customers around the world today.

C-FLAPS is based on fluorescent laser aerodynamic particle sizing technology pioneered by Dr. Jim Ho and his team at Defense Research and Development Canada – Suffield, a leading authority on aerosol science and applications of fluorescence excitation for biological identification. Commercialization of this technology and development of successive generations of FLAPS-based biological detection capability has been conducted by a working partnership between Dycor Technologies, TSI Incorporated and DRDC-Suffield, in a program of continuous improvement. C-FLAPS with its core FLAPS III (3317) Fluorescence Aerosol Particle Sensor technology has been adopted as a major component of the referee system by the US Air Force operational test and evaluation facility at Eglin Air Force Base in Florida, as well as at the US Army West Desert Test Center in Dugway, Utah, and at DRDC Suffield in Canada. C-FLAPS has also been designed for deployment with military forces in reconnaissance vehicles, naval platforms, and vital point protection configurations, and is fielded with a number of defense clients.

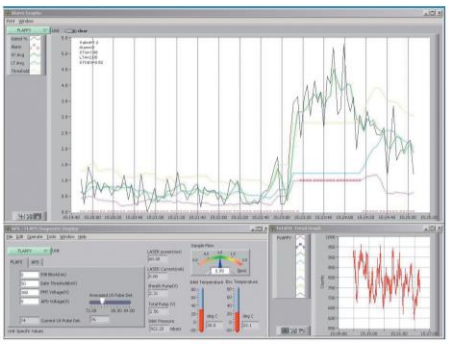
DYCOR™
The Intersection of Innovation and Technology

- C-FLAPS 生物預警系統內部裝設及 FLAPS 原理



- C-FLAPS 生物預警系統性能規格

CBNET's web interface.



CBNET is also capable of providing real-time location information, time stamped data based on a GPS-based system clock. Furthermore, a built-in TCP/IP server provides the user with the capability to connect CBNET to external third-party software programs, including command and control systems.

Communications

An Ethernet port allows customers worldwide to connect via cable or wireless radio based on their operational requirements. Additionally, as an option for the North American market, the C-FLAPS system can include an integrated FreeWave™ radio, which utilizes

Global Positioning System

C-FLAPS incorporates a COTS based GPS OEM receiver module to provide data time stamping and location information. This GPS receiver is a civilian module and complies with the NMEA 0183 protocol standard. Its primary purpose is to provide data time stamping. Location information is a secondary feature but this receiver is not intended to provide the same level of accuracy as found on military GPS receivers.

Specifications:

Dimensions	Width: 57 cm, Height: 73 cm (with stack), Depth: 39 cm
Weight	34 kilograms
Power Requirements	100 - 240V AC, 50/60Hz
Power Consumption	200 W
Laser Source	Laser diode, 30mW at 405 nm
Communications	10BaseT Ethernet; Optional Spread-spectrum, frequency-hopping, 902 MHz, 115kbaud max. data rate, 32 km. max line of sight.
Intake Flow Rate	0 – 350 standard liters (maximum) per minute (SLPM) @ 110V/220V AC (variable speed), +/- 25 SLPM
FLAPS Aerosol Flow Rate Sheath Air Flow Rate	1 liter per minute 4 liters per minute
Particle Size Range	Between 1 – 10 microns
Temperature Range	0 - 45°C (FLAPS III internal), 0-40°C (system operating)
Environmental Enclosure	Protection from rain designed according to Mil-Std 810F section 506.4 Proc 1 and 3.

- C-FLAPS 生物預警系統整合之 TSI-FLAPS III

FLUORESCENCE AEROSOL PARTICLE SENSOR™ (FLAPS)™ III SYSTEM MODEL 3317

LEVERAGE THREE MEASUREMENTS FOR BIOLOGICAL THREAT DETECTION

TSI's Fluorescence Aerosol Particle Sensor™ (FLAPS™) III System Model 3317 provides three real-time measurements of individual airborne particles. These correlated, single particle measurements give the FLAPS III exceptional discrimination and interference rejection for biological threat detection applications.

Applications

+ Trigger device for Point biological detection systems
+ Referee system for test sites
+ Fixed site, reconnaissance vehicles, and ship board applications

Features and Benefits

+ Fast response time
+ Three concurrent measurements of individual airborne particles provide low false alarm rates
+ Solid-state laser diode offers ruggedness and long life
+ Sheath air flow system keeps optics clean, minimizing maintenance

（三）國內代理商：邁帥生物科技公司

CHIEF PROTECTION
FIREFIGHTING AND CBRN DEFENCE

邁帥｜消防與核生化防護

≡ Navigation

- 歷史
- 滅火
- 呼吸
- 急救
- 偵測
- 機動

顯示全部類別 判別 蒐集 預警

XMX 攜帶式空氣採樣器

蒐集

SWIPE 檢體採樣組

SMART 生物戰劑判別紙碟

Profile 生物戰劑偵檢儀

固定式

人員攜帶式

車載式

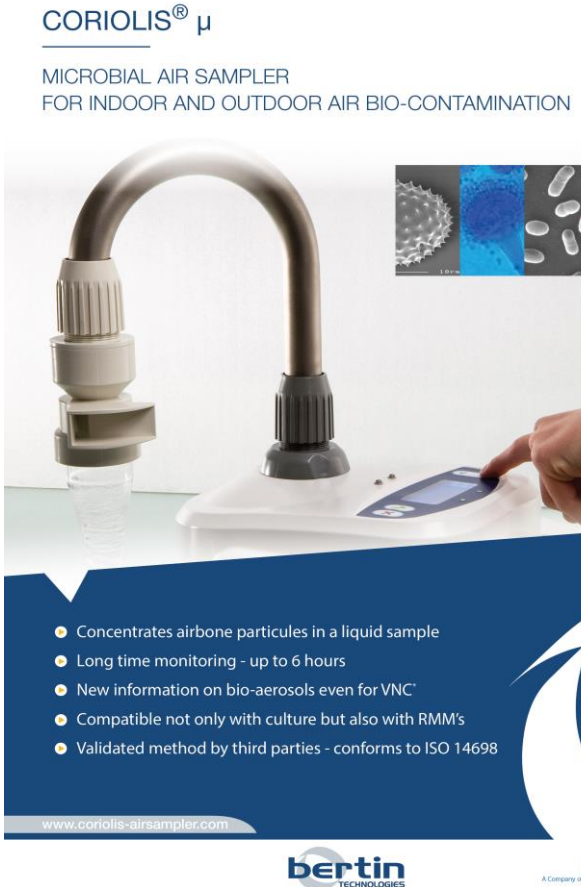
admin@chiefprotection.com

新北市淡水區中正東路二段29-3號22樓

+886-2-2808-3960

附錄二、法國 Bertin Coriolis® 儀器性能相關資料及國內代理商資訊

(一)Coriolis μ 空氣採樣器



- Coriolis μ 空氣採樣器及其性能規格

(二)Coriolis Delta 空氣採樣器及其規格

Coriolis® Delta air sampler

Coriolis® Delta, based on a patented technology, is a continuous cyclonic air sampler dedicated to outdoor air monitoring of pollen grains and fungi spores.

Delivering a liquid sample, this innovative air sampler is compatible with all detection technologies including molecular PCR and serological assay (ELISA) to assess the antigenicity / allergenicity of airborne particles.

- Long time monitoring up to 6 hours
- Flexible and easy set up
- Easy decontamination Autoclavable spare parts
- Weather-proof metal case
- Wind vane
- Sterile consumables

Technical specifications
Size: 330 x 370 x 260 mm
Weight: 7.8 kg
Power consumption : 100 W
Power requirements : 230 V, 50Hz
Operating temperature: + 5°C to + 45°C
Liquid injection : auto or fixe mode

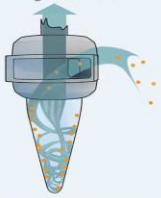
Air sampling module
Air flow rate: 100 to 300 LPM
Sampling times up to 6 hours

Get a liquid sample with concentrated particles compatible with all type of analysis (PCR, ELISA, optical microscope etc.)

Coriolis® Technology

Before aspiration
Cone ready to use with appropriate collection liquid

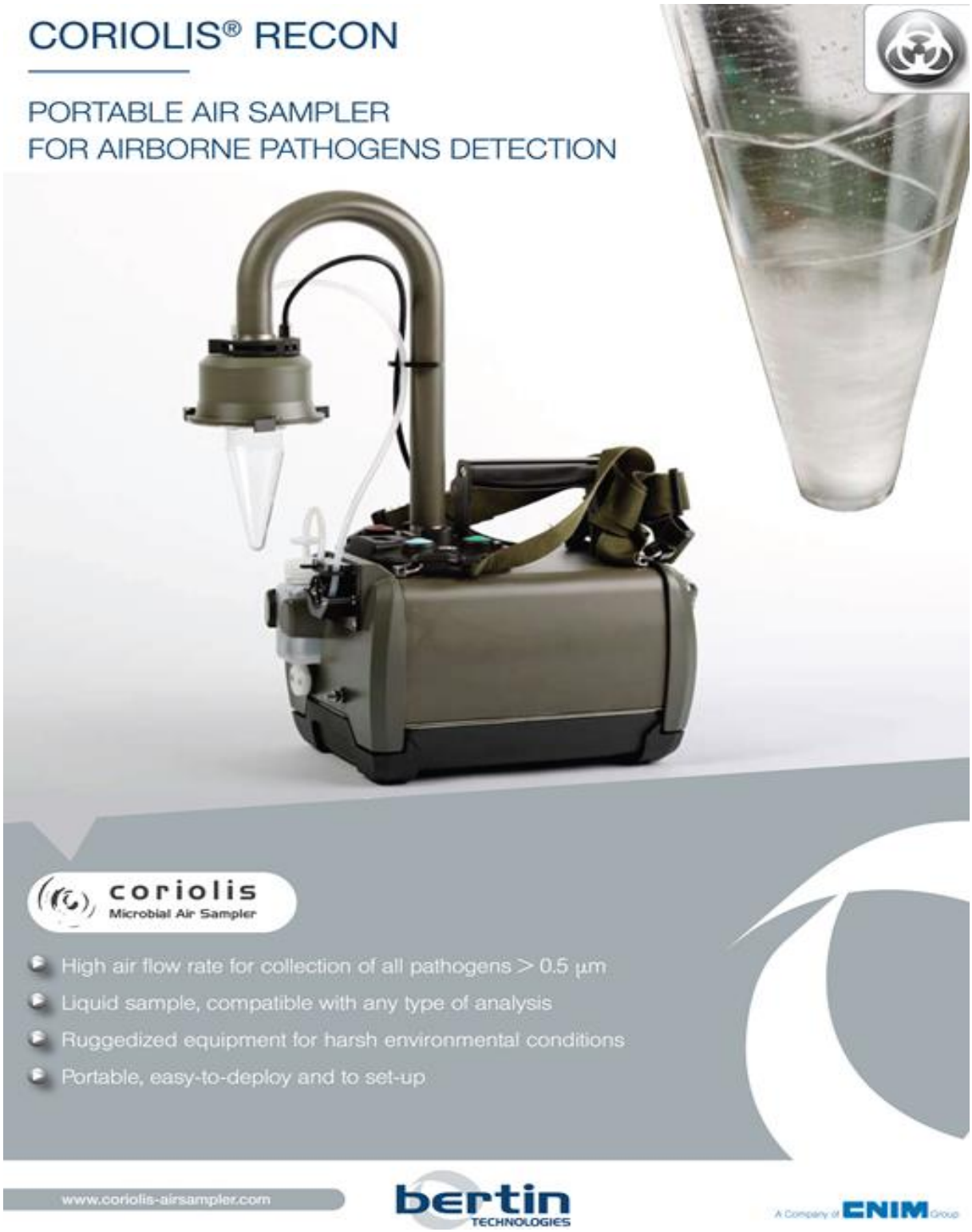
During aspiration
1.Vortex beginning
Air and particles come into the cone forming the vortex



During aspiration
2.During the vortex
Aspirated particles are centrifuged with the liquid on the cone's inner surface

Bertin technologies
www.coriolis-airsampler.com
E-mail : coriolis@bertin.fr
Phone : +33 (0) 139 306 070 - Fax : +33 (0) 139 306 185

(三)Coriolis Recon 空氣採樣器



- Coriolis Recon 空氣採樣器性能規格

Collection of airborne biological agents, virus, bacteria, toxins and spores.

Validated collection efficiency by third party testing.

Coriolis® RECON – a ruggedized bio-aerosol sampler

Coriolis® RECON is a ruggedized bio-aerosol sampler, dedicated to CBRN Recon teams or first responders, with quick deployment in case of bio-threat suspicion. Coriolis® RECON is efficient, portable and has been ruggedized for unfamiliar environment. Coriolis® RECON offers flexibility with a choice of operating modes:

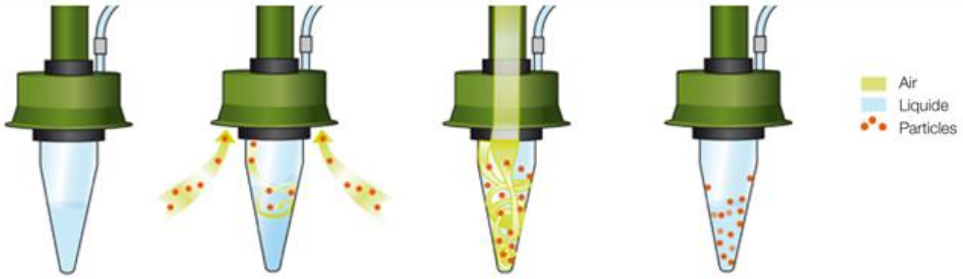
- Autonomous sampling: triggered by the operator wearing IPE; Coriolis® RECON can be used by Recon teams or first responders or for mobile applications to rapidly obtain a sample and identify the biological threat.
- Biological sentry mode: Coriolis® RECON can be set up in a standby mode, waiting for an order of a warning system.
- Long term surveillance: Coriolis® RECON can sample air up to 6 hours (Long Time Monitoring option).

Long Time Monitoring Option

Long Time Monitoring Option is available for the Coriolis® RECON. this option is ideal for the monitoring of a special area like Remote Base Surveillance.

This option adjusts automatically the volume of collection liquid for long sampling up to 6 hours. The volume of liquid inside the cone is always optimal for an efficient sampling.

Wet cyclone - a patented technology



Collection liquid is injected into the cone while aspirating.

Air is drawn in a whirling motion to form a vortex.

Particles are pulled against the wall due to centrifugal force, and separated from air to be concentrated into the liquid.

Technical features

Specifications	Coriolis® RECON
Application	Surveillance of critical areas
Principle	Wet cyclone
Collected particles size	> 0.5 µm
Air flow rate	600 L/min
Collection time	5, 10, 15 min - 6 hours with option
Watertight	Yes – IP54
Liquid sample	20 ± 5 ml
Dimensions (L x w x h)	365 x 220 x 306 mm without cane
Weight	10 kg (20 kg with case)
Autonomy	1h (collection time)
Main supply	100 – 240 V
Operating temperature	+ 5°C to + 49° C (+41° F to + 120°F) 0° C to + 49 ° C with the winter pack option

www.coriolis-airsampler.com
www.bertin.fr/en
coriolis@bertin.fr

Bertin Technologies

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Phone: (+65) 6444 6455

(四)Coriolis MS 空氣採樣器

CORIOLIS® MS

New generation tactical biological air sampler

FEATURE HIGHLIGHTS

- Bio-aerosols capture like anthrax, plague, etc.
- Liquid sample
- High air flow rate, long time monitoring
- Sample thermostatization
- Ergonomic and ruggedized design for field operation
- Portable and quick deployment
- Easy to decontaminate and sterile consumables

Coriolis*® *MS is a ruggedized bio-aerosol sampler, dedicated to area surveillance, in open field military conditions.

It has been designed to collect large concentrations of aerosols in the breathable range of 0.5 to 10 microns, thus being more representative of the environment than typical bio-aerosol samplers (high air flow rate).

Once the sample is collected, the user removes the vial for subsequent analysis (immuno-assay, PCR, culturing).

● Coriolis MS 空氣採樣器性能規格

GENERAL DESCRIPTION

Coriolis*® *MS offers flexibility with a choice of operating modes:

• *Autonomous point of care sampling:* this mode, triggered by the operator wearing IPE (Individual Protective Equipment), can be used by first responders or for mobile applications to rapidly obtain a sample and identify the biological threat (ideally with the ***KIM***).

• *Long time collection:* for the surveillance of a critical event, the long time collection mode (until 6 hours) can be used, to collect a sample that is fully representative of a given period of time.

• *Biological beacon mode:* for a long term surveillance (several days), ***Coriolis*® *MS*** can be set up in a standby mode, waiting for an order of a warning system, ideally the ***MAB.***

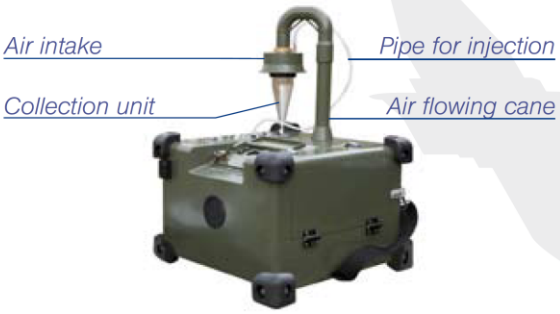
Coriolis*® *MS uses consumables:

A 500 ml collection liquid flask

A collection unit

SPECIFICATIONS

Specifications	***Coriolis*® *MS***
Application	Surveillance of critical area
Principle	Wet cyclone
Collected particles size	> 0.5 µm
Air flow rate	360 LPM to 630 LPM
Collection time	Up to 6 hours
Liquid sample	Up to 20 ml
Power requirements	- Battery (NiMH): 24 VDC or truck battery - Main supply: 220 VAC
Sample preservation	Yes
Liquid injection	Yes
Watertight	Yes
Weight	16 kg
Dimensions	460 x 460 x 332 mm
Operating temperature	+5°C to +45°C

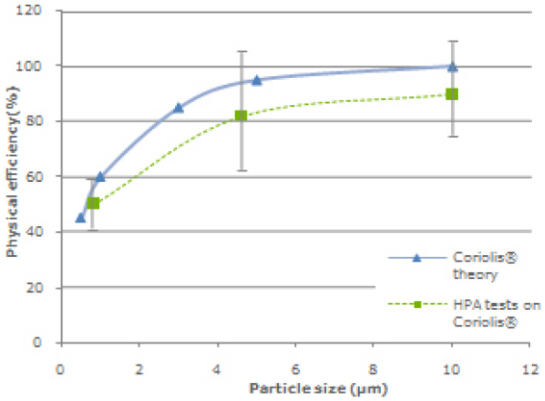


PRINCIPLE

Coriolis*® *MS air sampler is based on a wet cyclone: it collects high volumes of air and concentrates the aerosols into a liquid sample, adequate for all types of analysis (immuno-assay, PCR, culture, smart tickets, etc.)

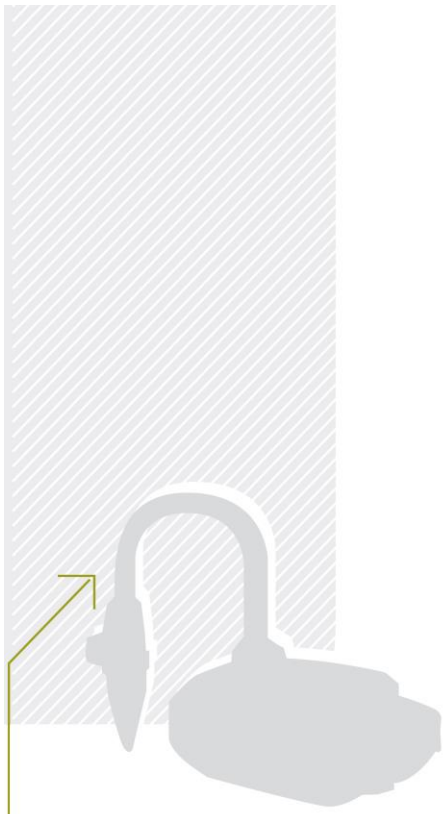
BIOLOGICAL QUALIFICATION

Biological efficiency of Coriolis® technology evaluated at the HPA (Health Protection Agency) – Porton Down



Coriolis efficiency has been evaluated by many organisms, in particular the CEB (Centre d'Etudes du Bouchet - France) and the HPA (Health Protection Agency - UK).
According to ISO 14698-1 annex 1, the biological efficiency of the Coriolis sampler, when compared to the standard low volume Casella slit sampler, was found to be 78% when using the aerostable E.Coli MRE162 strain (HPA).

(五) Coriolis FR 空氣採樣器



CORIOLIS® FR

Bio-air sampler for first responder

FEATURE HIGHLIGHTS

- Bio-aerosols capture like anthrax, plague, etc.
- Liquid sample
- Compact and portable
- Easy to deploy and set up
- Easy decontamination
- Sterile consumables

Coriolis*® *FR is a bio-aerosol sampler, dedicated to first responders, with quick deployment in response to a civilian or military event.

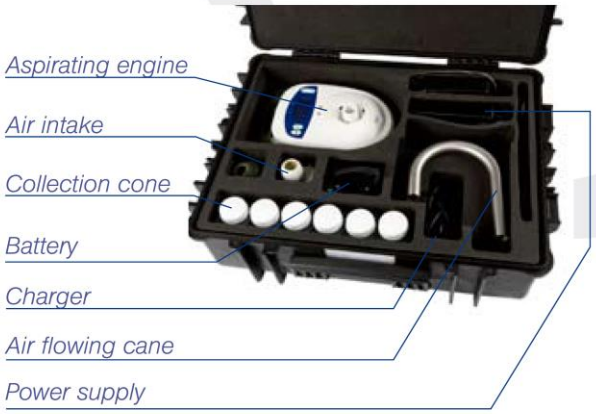
It has been designed to collect large concentrations of aerosols in the breathable range of 0.5 to 10 microns, thus being more representative of the environment than typical bio-aerosol samplers .

Thanks to its liquid sample, it can be used with a rapid identification system (immunoassay, PCR, etc.) to provide an early warning of aerosolized biological warfare agents.

- Coriolis MS 空氣採樣器性能規格

GENERAL DESCRIPTION

Coriolis*® *FR is efficient and light. It is ruggedized for uses in unfamiliar and dangerous environments. Additionally it can be completely decontaminated by classical disinfectants (vapour of hydrogen peroxide, bleach).



SPECIFICATIONS

Specifications	***Coriolis*® *FR***
Application	First responders
Principle	Wet cyclone
Collected particles size	> 0.5 µm
Air flow rate	100 to 300 LMP
Collection time	10 min
Liquid sample	Up to 15 ml
Power requirements	100/240 V
Lifespan	Battery: 2 hours
Watertight	Yes
Weight	4 kg (+ case: 15 kg)
Dimensions	220 x 330 x 140 mm (without flowing cane)
Operating temperature	+5°C to +45°C

PRINCIPLE

Coriolis*® *FR air sampler uses the same principle as the ***Coriolis*® *MS***, which is a wet cyclone. It collects high volumes of air and concentrates the aerosols into a liquid sample.

BIOLOGICAL QUALIFICATION

Coriolis*® *FR has been tested by the WIS (Wehrwissenschaftliches Institut für Schutztechnologien - ABC-Schutz – Germany) with a demonstrated biological efficiency of 70 % respective to the reference sampler (All Glass Impinger 30) on spores of Bacillus atrophaeus (1 µm).

Reports available from international independent and recognized laboratories on demand.

國內代理商: 科安企業股份有限公司

附錄三、美國 SKC 空氣採樣器及國內代理商資訊

(一)SKC BioStage 衝擊板式生物氣膠採樣器

細菌：Tryptic Soy Agar(TSA)或Blood Agar Plates(BAP)
真菌：Potato Dextrose Agar(PDA), Malt Extract Agar(MEA), Dichlorann Glycerol 18 Agar(DG-18)或Corn Meal Agar(CMA)

- 採樣時間：少於10分鐘
- 採樣速率：STD BioStage - 28.3公升/分鐘，BioStage 200 – 14.15公升/分鐘
- 採樣幫浦：SKC QuickTake 30
- 採樣介質：洋菜培養基(60-100mm之培養皿)
- 採樣器重：600公克以內 (不含採樣幫浦)
- 分類層：標準BioStage為400洞，BioStage 200為200洞

產品敘述	產品編號
標準BioStage單階生物氣膠衝擊採樣器，400孔	225-9611
BioStage 200單階生物氣膠衝擊採樣器，200孔	225-9610
BioStage生物氣膠採樣組-AC. 包含標準型生物氣膠採樣器，真空幫浦，附浮子流量計，校正接管的接頭、接管、採樣腳架與攜行箱。 無CE標記。 115V	225-9535K
BioStage生物氣膠採樣組-DC. 包含標準型生物氣膠採樣器，攜行充電式真空幫浦(QuickTake 30)，AC充電器及接頭、校正接頭、浮子流量計、接管、採樣腳架、攜行整理箱。100-240V	228-9530K
採樣腳架，5英呎(1.5公尺)高	225-9536
BioStage安置在QuickTake 30上的固定座	228-9531
流量校正接頭	P33100
大零環(O-ring)	P31893
小零環(O-ring)	P32287

- SKC BioStage 衝擊板式生物氣膠採樣器應用與產品說明

BioStage Viable Cascade Impactors

Applications

- Indoor Air Quality (IAQ) studies
- Filter and cleanroom efficiency studies
- Pharmaceutical production
- Brewery fermentation
- Animal care laboratories
- Food processing areas
- Sewage treatment plants
- Hospital environments
- Cosmetic manufacturing
- Grain processing and transportation
- Bio-risk response

Operation

The BioStage impactors are easy to use. A barbed outlet fitting allows fast and easy connection to a vacuum pump. The SureLock positive seal keeps the jet classification stage and agar plate securely in place and prevents leakage during sampling. Sampling is as simple as sealing an agar plate inside the BioStage, connecting the impactor to a pump operating at the appropriate flow rate, sampling for two to five minutes, removing the agar plate, and sending it to a qualified laboratory for analysis.

About the BioStage 200

In addition to the standard BioStage, SKC offers the BioStage 200 with a 200-hole jet classification stage. Designed to cut the sampling job in half, BioStage 200 accommodates a 90 to 100-mm agar plate and requires only a 14.15 L/min flow rate.

References:

Macher, J., (ed.) Bioaerosols: Assessment and Control, ACGIH, 1999

Macher, J., "Positive-hole Correction of Multiple-jet Impactors for Collecting Viable Microorganisms," American Industrial Hygiene Journal, 50 (11), 1989, pp. 561-568, available at www.skcinc.com/pdf/Multiple_Jet_Impactors.pdf

Samimi, B. and Shufutinsky, A., "Comparison of the Thermo-Andersen N6, the Aerotech A6, the SKC BioStage, and the SKC Micromedia Viable Samplers in Collecting Airborne Fungal Spores," AIHce 2005, San Diego, CA, Final Program, p. 43

Yao, M. and Mainelis, G., "Analysis of Portable Impactor Performance for Enumeration of Viable Bioaerosols," Journal of Occupational and Environmental Hygiene, Vol. 4, Issue 7, July 2007, pp. 514-524

Performance Profile

Flow Rate: **Standard BioStage:** 28.3 L/min; **BioStage 200:** 14.15 L/min

Material: **Inlet cone and base plate:** Precision-tooled autoclavable aluminum; **O-rings:** Duro 50, BUNA-N *(not autoclavable)*

Jet Classification Stage: **Standard BioStage:** 400 holes *(0.25-mm hole diameter)*; **BioStage 200:** 200 holes *(0.25-mm hole diameter)*

Median Cut-point (D_{50}): 0.6 µm

Sample Media: 90 to 100-mm agar plates*

Suggested Media:

For bacteria:
Tryptic Soy Agar (TSA)
Blood Agar Plates (BAP)

For fungi:
Potato Dextrose Agar (PDA)
Malt Extract Agar (MEA)
Dichloran Glycerol 18 Agar (DG-18)
Corn Meal Agar (CMA)

Analysis: Colony culture *(see Positive-hole Correction reference below left)*

Tubing: 1/4-inch ID

For a list of laboratories that can provide agar plates and analyze samples, visit the SKC website at www.skcinc.com. Click on *Laboratories* or visit the AIHA website at www.aiha.org.

Ordering Information

Description	Cat. No.
Standard BioStage* single-stage viable cascade impactor	225-9611
BioStage 200* single-stage viable cascade impactor	225-9610
BioStage Pump Kit-DC includes Standard BioStage*, QuickTake 30 pump with battery, AC charger/adapter (100-240 V), mounting bracket with inlet adapter, calibration adapter, field rotameter, tubing, and deluxe carry case	228-9530K
Accessories	
QuickTake 30 Sample Pump,¥ Rotameter, and Charger 100-240 V	228-9530A
Calibration Adapter for BioStage, allows tubing to connect to BioStage inlet. *Suitable for both models*	P33100
Mounting Bracket for QuickTake 30, holds BioStage in place on pump during sampling	228-9531

* *Requires microbiological media supplied by analytical laboratories. For lab list, go to www.skcinc.com/labs/225-9611-labs.asp.*

¥ *Do not operate or charge in hazardous locations. Not UL Listed for intrinsic safety. Not CE marked.*

SKC Inc. 724-941-9701 SKC-West 714-992-2780 SKC Gulf Coast 281-859-8050 SKC South 434-352-7149
www.skcinc.com

(二)國內代理商: 科安企業股份有限公司

附錄四、美國 Research International 儀器及性能相關資料(目前國內無代理商)

(一)SASS 系列各式空氣採樣器及其性能表

SASS 2300 WETTED-WALL AIR SAMPLER

Sample fluid is maintained at a constant amount independent of collection time, ambient air temperature, or relative humidity, providing unsurpassed monitoring capabilities in environments ranging from farmyards to hospitals to battlefields.

SASS 2400 LOW-VOLUME WET AIR SAMPLER

Lower air flow and fluid sample volume, while still employing the highly successful wetted wall aerosol collection strategy that has received DHS Certification under the U.S. Safety Act of 2002.

SASS 3100 DRY AIR SAMPLER

A high efficiency dry filter sampler developed for the collection of airborne particulates, especially pathogenic bacteria and spores.

SASS 3100R RADIOACTIVE DRY AIR SAMPLER

Built on our proven SASS 3100 dry air sampler, it is a portable aerosol collector developed specifically for Research International's air-borne radioactivity electret collection filter.

SASS 4100 TWO-STAGE COLLECTOR

Directs the SASS 4000 secondary airflow through an electret filter media from which the particles can later be extracted for detection and analysis.

- SASS 2300 濕式空氣採樣器性能規格

SASS 2300 Wetted-Wall Air SamplerSpecifications	
Characteristic	**Description**
Operating principle	Multi-stage wetted-wall cyclone with enhanced particulate collection.
Air collection rate	325 LPM using 30,000 hr. life brushless fan.
Particulates collection range	1-10 µm. Contact Research International regarding vapor collection applications.
Concentration ratio	78,000/minute, nominal.
Liquid inventory	4-5 cc range, adjustable by user. Proprietary control loop maintains a constant liquid volume in the sampler, independent of collection time, temperature, or humidity; useful for concentrating trace airborne analytes.
Make-up water	1 liter on-board reservoir; supplemental off-board reservoirs may be used in fixed installations: 0.8 cc/min, typical evaporation rate at 20C/50% RH.
Physical size	18.4 cm x 21.3 cm x 34.3 cm (7.2" W x 8.4" D x 13.5" H).
Weight	3.7 kg without battery, 4.7 kg with battery (8.2/10.4 lbs). Add 1 kg (2.2 lbs) for 1 liter of water.
Air inlet	Industry-standard threaded adapter.
Humidity range	Non-condensing conditions.
Operating temperature	Above freezing conditions to 66^{O} C.
Power source	BA-5590/U primary battery; or BA-5390/U extended life primary battery; or UBI 2590 rechargeable battery; or 82-265 Volt (47-63 Hz) AC lump-in-cord power supply.
Power consumption	1.33 amps @ 12 V, 16 W.
Sample extraction	On-board 12 cc/min peristaltic pump, manual or remotely controlled. Vial filling module included. Air sampling may continue during extraction.
System controls	Microprocessor controlled. RS-232 or optional wireless link for remote operation or reprogramming. Additional TTL and motor drivers available.
PC interface requirements	OS: Windows Server 2003/2008, Vista or XP. Processor: 400 MHz Pentium or equivalent (Min.). RAM: 96 MB (Min.), 256 MB (Recommended). Hard Disk: 1.2 MB available space. CD-ROM.
Sound level	60 dB (A).
Package	Lightweight two-piece molded plastic shell with swivel-style carrying handle.
Decontamination	Auto-flush protocol using onboard water, or manual flush with detergent and/or disinfectant. Disposable fan module.
Accessories	Carrying case; inlet hose; 8cc sample bottles; sample bottles; rechargeable battery and charger.
Approvals	U.S. Dept. of Homeland Security certified under U.S. Safety Act of 2002
Research International reserves the right to change specifications without prior notice.	

- SASS 2400 低通量濕式空氣採樣器性能規格

SPECIFICATIONS for SASS 2400 and 2400-OEM	
Characteristic	**Description**
Operating principle	Multi-stage wetted-wall cyclone with enhanced particulate collection.
Air collection rate	40 LPM using 30,000 hour life brushless fan.
Particulates collection range	1-10 µm. 70% collection efficiency at 3 micron particle size.
Concentration ratio	40,000/min., nominal.
Liquid inventory	1 cc; set at factory. Proprietary control loop maintains a constant liquid volume in the sampler, independent of collection time, temperature or humidity; useful for concentrating trace airborne analytes.
Make-up water	1.3 liter on-board reservoir; supplemental off-board reservoirs may be used in fixed installations: 0.1 cc/min typical evaporation rate at 20C/50% RH.
Physical size	18.4 cm x 21.3 cm x 34.3 cm (7.2" W x 8.4" D x 13.5" H).
Weight	3.7 kg without battery, 4.7 kg with battery (8.2/10.4 lbs). Add 1 kg (2.2 lbs) for 1 liter of water.
Air inlet	15.4 mm diameter tube stub. It is recommended that third-party accessories have an airflow channel of comparable diameter or larger.
Humidity range	Non-condensing conditions.
Operating temperature	Above freezing conditions to 66^{O} C.
Power source	12 VDC BA-5590/U primary battery; or BA-5390/U extended life primary battery; or UBI 2590 rechargeable battery; or 82-265 Volt (47-63 Hz) AC lump-in-cord power supply.
Power consumption	Power consumption 12 V @ 0.75A, 9 W
Sample extraction	On-board 12 cc/min peristaltic pump, manual or remotely controlled. Vial filling module included. Air sampling may continue during extraction.
System controls	Microprocessor controlled. RS-232 or optional wireless link for remote operation or reprogramming. Additional TTL and motor drivers available.
Sound level	70 dB (A).
Package	Lightweight two-piece molded plastic shell with swivel-style carrying handle.
Decontamination	Auto-flush protocol using onboard water, or manual flush with detergent and/or disinfectant. Disposable high-performance pull-through fan module.
Accessories	Carrying case; inlet hose; 8cc sample bottles; sample bottles; rechargeable battery and charger.
Approvals	U.S. Dept. of Homeland Security certified under U.S. Safety Act of 2002
Research International reserves the right to change specifications without prior notice.	

- SASS 3100 乾式空氣採樣器性能規格

SASS 3100 Specifications	
Characteristic	**Description**
Operating Principle	Electret dry filter media with high efficiency centrifugal fan.
Air Collection Rate	User adjustable 50 LPM to 310 LPM typical
Collection Efficiency	0.5 μm dia: 50% 1.0 μm dia: 75% >2.0 μm dia: 90%
Fan Life	Fan life is 30,000-40,000 operating hours.
Operating Temp. Range	-40 to 70°C
Storage Temp. Range	-40 to 70°C
Humidity Range	All-weather. Optional rain shield prevents wetting of filter during rainy conditions.
Decontamination	Ethylene oxide, vapor phase hydrogen peroxide or 5% sodium hypochlorite solution.
Physical Size	
– Filter media	4.4 cm diameter active filter in 6.0 cm diameter holder.
– Overall Case	15.60 x 17.04 x 19.81 cm with handle. 15.60 x 14.53 x 19.81 cm without handle.
Weight	2.0 kg; add 1 kg for battery
Power Source	BA-5590A/U primary battery or BA-5390/U extended life battery; UBI-2590 rechargeable battery; Universal wall supply: 82-265 Volt (47-63 Hz).
Power Consumption	8.4 W (>24 hrs operation with primary batteries; >20 hrs with rechargeable battery).
Connectors	• Standard: DB-9 • Optional: Military CCSI (additional cost)
System Controls	Microprocessor controlled. Dimmable LEDs monitor for battery end-of-life and fan rotation.
PC Interface Requirements	OS: Windows Server 2003/2008, Vista or XP. Processor: 400 MHz Pentium or equivalent (Min.). RAM: 96 MB (Min.), 256 MB (Recommended). Hard Disk: 1.2 MB available space. CD-ROM.
Communications	RS-232 or optional RF link for remote operation or reprogramming.
Sound Level	45-61 dB (A) at 1 meter; peak value at exhaust port
Package	EMI resistant, water-tight aluminum extrusion
Mounting	Standard ¼-20 camera thread on unit handle and base.
Research International reserves the right to change specifications without notice.	

- SASS 4000/4100 高通量濕式空氣濃縮採樣器性能規格

Specifications for SASS 4000 Concentrator	
Characteristic	**Description**
Primary airflow	3,600+ liters/min is sampled uniformly from around the concentrator's circumference.
Secondary airflow	30-325 LPM at +0.4 cm of water static head.
Secondary airflow connection	Hose barb fitting on base surface for nominal 3.8 cm ID hose.
Concentration enhancement	4 - 15 times, typical, depending on primary/secondary airflow ratio.
Overall size	38 cm high x 25.4 cm diameter max.
Weight	6.32 kg (13.9 lbs.)
Operating temperature range	-40°C to 60°C
Power consumption	▪ 90 watts for ECM drive motor. If operated from DC, please specify DC source voltage of 12, 24 or 28 VDC. ▪ 100 to 230 VAC lump-in cord AD/DC converter supplied. Please specify AC voltage range required.
Sound level	72 db-A @ 1 meter radius on inlet equatorial plane.
Mounting	Quick-detach tripod legs; 0.53m to 1.46m adjustable height.
Accessories	• Hard shell carrying case. • Electret sample filter assembly (for stand-alone operation).
Research International reserves the right to change specifications without prior notice.	

(二)BioHwak 八通道空氣採樣暨生物偵測器

BioHawk 8-Channel collection and bioidentification system.

BioHawk® is a portable 8-channel bioassay system integrated with an aerosol collector. It is suitable for the high-sensitivity monitoring of biological agents, toxins, explosives, and chemical contaminants. Assay results are typically available in 10 to 20 minutes. BioHawk can be programmed to monitor surrounding air for aerosol threats with the built-in air sampler, and to periodically transfer a wet concentrate from the air sampler to the bioidentifier portion.

Bioassays are performed within a small disposable credit card-sized plastic assay coupon, which can be used for up to10 assay procedures before being discarded. Since a single assay coupon can handle up to eight different analytes simultaneously, up to 80 individual assays can be performed before discarding or removing the coupon. Assay results are transmitted a through the touch panel LCD display, an audible alarm, a pulsating light, or by Bluetooth wireless or RS-232 link to personnel at a remote location. System operation may also be remotely controlled in real time.

Functions such as air sampling and bioidentification are performed using multi-step recipes developed by Research International and stored in the system's computer memory. Users need only the most fundamental level of training since the internal processes and steps are preset through the built-in computerized recipes. For more advanced users, Windows-based software allows the user to develop their own customized sample collection and detection protocols.

For more technical information visit www.resrchintl.com.

FEATURES

- Portable. Weighs less than 30 pounds.
- Enhanced particulate collection.
- Air collection at 325 LPM, nominal.
- Disposable wet assay coupon. Reusable up to 10 times.
- Fast assays: 10 - 15 minutes typical.
- Auto-flush protocols for decontamination.
- Analyte range: toxins, bacteria, spores, fungi, multi-cellular pathogens.
- Sensitivity: analyte dependent, 1 to 10 ppb typical for toxins, 100 to 100,000 CFU/ml for bacteria.
- Designed to MILSPEC 810F.
- Flash memory retains raw / processed data for over 6,000 assays.

APPLICATION AREAS

- Medical
- Agriculture
- Military
- Homeland security
- Environmental
- Indoor air quality

- 上列 SASS 系列儀器均設計可增設無線模組串連操作及收取訊號

- BioHwak 八通道空氣採樣暨生物偵測器性能規格

General Specifications for BioHawk 8-Channel Collector/Bioidentifier	
Characteristic	**Description**
Use profile	Indoor/outdoor sample collection, transfer, and assay; storage of 255 assay recipes; user in full MOPP gear either walking or in moving vehicle.
Collection principle	Multi-stage wetted-wall cyclone with enhanced particulate collection.
Assay method	Disposable wet assay coupon is re-useable up to 10 times. Eight simultaneous software-based assays. Antibody or nucleic acid. Coupon reseals on removal for archival storage.
Fluid Handling	Fluids manipulated under microprocessor control using peristaltic and syringe pumps; sample may be oscillated to lower assay time; reagent is recovered for reuse.
Fluids storage	Snap on 3-section fluid pack. Clean water: 1 liter; Buffer: 250 ml. Waste: 500ml. Assay samples may be optionally stored in a detachable 8cc vial for later analysis.
Human interface	Day/night Touchscreen LCD display. Usable in MOPP gear.
Digital communication	RS-232 bi-directional serial link
Physical size	35.6 cm W x 36.5 cm H x 17.1 cm D
Weight	21.7 lbs. dry; 26.7 lbs. with battery and fluids (9.8/12.1 kg).
Operating/storage	1 to 66°C and -29 to 66°C. Reagent deterioration can reduce upper limit significantly
Humidity	10% and above. May be operated in rain.
Survivability	MILSPEC 810F; MTBF of about 30,000 hours is determined by air sampler fan
Data storage	Flash memory retains raw/processed data for over 6000 assays.
Power Consumption	6.2 W at idle; 17.8W with fan operating and one assay performed each 30 minutes.
Power source	Primary battery BA-5390A/U, 1.05 kg (2.3 lb); lifetime 14 to 45 hours. Rechargeable battery UBI-2590; lifetime is approximately 56% of the BA5390A/U primary battery. Universal lump-in-cord power supply, 82-265 Volt (47-63 Hz).
Alarm	Visual LED and 103 dB @0.6m waterproof horn; adjustable. RS-232 data link.
Decontamination	Auto-flush protocols using onboard water, or manual flush with detergent and/or disinfectant. High-performance pull-through fan easily remove if contaminated.
Sound level	60 dB (A).
Ancillary equipment	Heavy-duty hard-shell transport case with wheels.
Bioassay Specifications	
Analyte range	Toxins, viruses, bacteria, spores, fungi, multicellular pathogens
Sensitivity	Analyte dependent, 1 to 10 ppb typical for toxins, 100 to 100,000 CFU/ml for bacteria.
Assay time	Dependent on assay; 10 to 20 minutes typical
Reagent storage	Reagent stored onboard assay coupon; may be reused up to 15 times depending on assay protocol.
Confirmatory sample	Confirmatory sample may be stored in assay coupon or 8cc sample vial.
Air Sampling Specifications	
Air collection rate	325 LPM, nominal.
Particulates collection range	1-10 µm
Concentration ratio	65,000/min., nominal
Liquid inventory	4 to 5cc. Factory set but adjustable under computer control. Patented control process maintains a constant liquid volume in the sampler, independent of collection time, temperature, or humidity; useful for concentrating trace airborne analytes.
Air inlet	Screened rectangular opening. Hose adapters available.
Research International reserves the right to change specifications without prior notice.	

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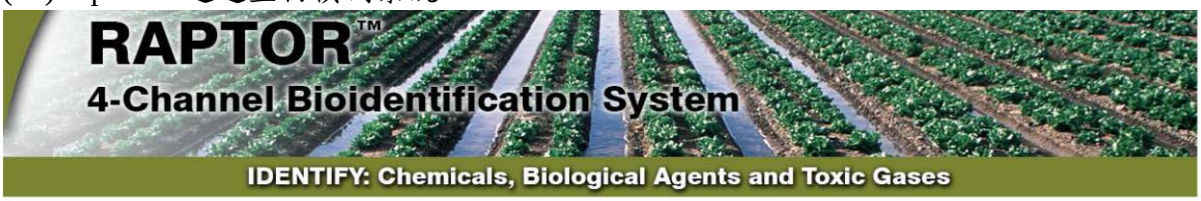
(三)Raptor 四通道生物偵測系統



RAPTOR 4-channel bioassay system.

The RAPTOR™ is a portable, 4-channel fluorometric assay system that can be used for high-sensitivity monitoring of biological agents, toxins, explosives, and chemical contaminants. It is a careful integration of optics, fluidics, electronics, and software into one compact system for use in laboratory settings and field assays. This unit can automatically perform a user-defined, multi-step, assay protocol while simultaneously tracking fluorescently-tagged chemical reactions occurring on the surface of each of the system's four disposable optical waveguide sensors.

Using immunoassay techniques, toxins and markers such as Y. pestis F1 antigen have been detected at levels below 1 ppb from samples of a few hundred microliters. Each waveguide may be functionalized with a different assay, allowing up to four different assays to be run simultaneously. The results of these assays are displayed on a four line x 16 character LCD. The RAPTOR can also be run from a desktop PC, via an RS-232 link, using Windows-based software that is provided with the system.

The RAPTOR uses a disposable plastic coupon containing four injection-molded optical waveguides. These wave-guides are functionalized with the desired chemistry and inserted into the coupon. They are then simultaneously interrogated using 635 nm light while monitoring the return fluorescent signal. To run an assay, the user simply inserts a coupon and presses the Run Assay key. Assays typically take between 10 to 15 minutes and the results are displayed on the four line x 16 character LCD for each of the four waveguides.

Windows-based software allows the user to graphically monitor data recovery while an assay is running.

For more technical information visit www.resrchintl.com.

FEATURES

- Compact, portable system (about the size of a car battery)
- Immunoassay-based biosensor for real time or near real time detection of microbial pathogens
- Typical assay times of 10-15 minutes
- Coupons may be reused if test results continue to be negative
- Successfully used with urine, whole blood, milk, marine water, 10% meat slurries and slurries of human waste.

APPLICATION AREAS

- Water quality monitoring
- Laboratory testing
- Food safety monitoring
- Medical
- Agriculture
- Environmental
- Homeland security
- Mailrooms
- UAV's (Unmanned Aerial Vehicles)

- Raptor 四通道生物偵測系統性能規格

RAPTOR™ SPECIFICATIONS	
Parameter	**Value**
Use profile	Indoor/outdoor sample collection, transfer, and assay; storage of 63 assay recipes; user in full MOPP gear either walking or in slowly moving HumVee.
Physical size	18.6 cm L x 27.4 cm H x 17.3 cm W
Weight	5.6 kg (w/o battery)
Operating temperature range	1 to 35°C
Storage range	-29 to 66°C
Assay coupon	Four simultaneous assays, disposable, coded for assay identification. Coupon reseals upon removal for archival storage.
Fluids storage	On-board storage of buffer and reagent. Reagent stored at constant temperature in reusable thermal storage module.
Sensitivity	Dependent on analyte, 1 to 10 ppb is typical.
Assay time	Dependent on assay, 9 to 13 minutes is typical.
Data/command entry	Day-night visible keypad and display, usable in MOPP gear.
Visual	Liquid crystal display; display provides positive/negative/retest for each agent.
Communication	RS-232 bi-directional serial link and DB-15 accessory connector.
Data storage	EEPROM retains raw/processed data for over 200 assays.
Batteries	Primary battery BA-5590/U, 1.05 kg (2.3 lb); lifetime 9 to 24 hours.
Humidity	20 to 90%, noncondensing.
Ancillary equipment	Nylon twill photographer's-style case, carry strap compatible with MOPP gear; weight 1.2 kg (2.6 lb.); lump-in-cord power supply.
Accessories support	Three digital input lines and six software-controlled external drivers.

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附錄五、美國 FLIR 儀器及性能相關資料(目前國內無代理商)

(一)FIDO B1/BioCapture 650 便攜型乾式空氣採樣器

PRODUCT OVERVIEW

BioCapture® 650

PORTABLE AIR SAMPLER

The BioCapture® 650 was designed for first responders working in unfamiliar, challenging and dangerous environments. We know that emergency situations are no place for chemistry set-ups and delicate instrumentation. The BioCapture is cutting-edge air sampling technology packed in a rugged, lightweight package. Large single button operation means responders can quickly execute the sampling mission and proceed to other objectives.

The key to the BioCapture is the integrated collector cartridge. With the rotating impactor, fluid chamber, fluid lines and sample vial pre-assembled in one disposable cartridge, the system is deployment ready when you are. When the operation is complete, simply replace the cartridge and you are ready for your next mission. There are no internal lines to decontaminate, no sand or dirt to clean out of moveable parts and corners. Simplify your biosampling preparedness program with the BioCapture.

FEATURES

- Single button operation in hot zone
- Deployment ready for emergency use
- Laboratory effectiveness in a rugged 7.5 lb package
- Collects typical agents released in a bio-threat attack including bacterial spores (such as *B. anthracis*, which causes anthrax), bacteria (such as *Y. pestis*, which causes plague), viruses (such as smallpox) and toxins (such as ricin)
- 100% decontamination ability
- Highly operable in sand, dust and inclement environments
- Flexible sampling times
- Disposable collector cartridge prevents cross contamination
- Easy to operate by user in fully dressed Level A or MOPP-IV gear

- FIDO B1/BioCapture 650 便攜型乾式空氣採樣器性能規格

The BioCapture represents a significant leap forward in air sampling technology. Incorporating the latest technological breakthroughs in particle collection, the portable, handheld unit captures airborne pathogens and spores into a concentrated liquid sample. A snap-in, disposable sampling cartridge minimizes set-up and decontamination. The BioCapture provides the user with an effective and easy to use instrument for fast, safe and efficient biological agent collection.

The BioCapture collects micron and submicron airborne particles. The battery-powered system is ideal for indoor and outdoor tactical response to potential threats such as anthrax, plague, smallpox and tularemia. Whether the user is operating in a hot zone dressed in Level A or MOPP-IV gear or performing intermittent air sampling in a mail room, operating the BioCapture is effortless and extremely cost effective.

SPECIFICATIONS

Height	5.25 in (13.3 cm)
Width	6 in (15.2 cm)
Length	14.5 in (37 cm)
Weight	7.5 lbs (with battery and cartridge)
Sampling Flow Rate	200 liters per min
Particle Size Collection	0.5 to 10 microns
Liquid Sample Volume	2 to 5 ml
Sampling Times	5, 15, 30 and 60 min
Power Supply	Lithium Ion battery
Electrical	12 VDC, 26 watts
Operating Angle	0° to 20° (horizontal)
Operating Temperature	35°F to 110°F (2°C to 43°C)
Storage Temperature	-51°F to +140°F (-46°C to +60°C)
Operating Humidity	5% to 95%, non-condensing
Operating Altitude	Up to 15,000 ft
Rain	Water-tight; 1.8 in per hour in 20 mph wind for 30 minutes

FLIR®
Extraordinary Protection

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(二)FIDO B2/IBAC 生物氣膠偵測收集器/即時生物預警系統

FIDO® B2

Instantaneous Biological Aerosol Detector and Collector with IBAC Technology

The Fido® B2 is a fully automated biological agent detector that alarms in less than 60 seconds when an airborne bio-threat is present. Its IBAC™ technology uses UV-Laser induced fluorescence to discriminate biological organisms from background particles, reliably detecting all four classes of bio-agents at concentrations below 100 ACPLA with low false alarm rates. The Fido B2 system can operate independently, as part of a network configuration to form the "first tier" of a building protection system, or via battery power module for mobile detection capability. Its four stages work together continually to monitor the environment for the presence of bio-threats, alarm upon detection, collect and preserve samples for confirmatory analysis, and transmit data to command and control centers. From long-term, fixed installations to short, mission-based tactical applications, the Fido B2 offers a flexible, field-ready solution for bio-aerosol monitoring.

CUSTOMER APPLICATION

- Building Protection
- Special Event Monitoring
- Mission-Based Incident Response
- Force Protection
- Mass Transit Security
- Mobile Labs
- Integrated CBRNE Systems

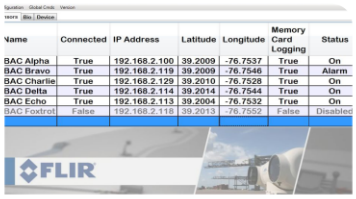
FEATURES AND BENEFITS

- Provides affordable, real-time warning capability for biological aerosol threats
- Most mature and widely deployed bio-trigger device on the market today
- Detects all four classes of bio-organisms: spores, vegetative, virus, and toxins
- Autonomous 24/7 operation with no consumables or regular maintenance
- Alarm automatically triggers sample collector for subsequent identification
- Alert algorithms validated for both indoor and outdoor environments
- Integrates with most facility monitoring and control systems
- Government validated with over 1,000 sensors deployed in relevant bio-monitoring applications

- FIDO B2/IBAC 生物氣膠偵測收集器性能規格

Detector Specifications

Detector Specifications:	
Detection Technology	UV – LIF, Excitation Wavelength = 405 nm
Power Consumption	20 Watts (normal detector operation) 75 Watts (with collector running)
Input Voltage	18-36 VDC 100–240 VAC, 50-60Hz (with AC power adapter)
Dimensions (L x W x H)	9.5 x 6.5 x 9.0 inches (24 x 16.5 x 23 cm), no battery 9.5 x 6.5 x 12.0 inches (24 x16.5 x 30.5 cm), with battery pack
Weight	7.5 lbs (3.4 kg) no battery 13.0 lbs (5.9 kg) with battery
Communication	Ethernet, RS-232 Optional embedded wireless (900MHz or 2.4GHz)
Air Flow Rate	3.8 liters/minute, 0.13 ft³/minute (cfm)
Operating Temperature	-5 to +125 °F (-20 to +50 °C)
Storage Temperature	-40 to +160 °F (-40 to +70 °C)
Operating Time	Continuous 24/7/365
Outputs	Particle Data, Sensor Diagnostics, Bio-Alarm, Fault
Data Storage	Internal MicroSD Memory Card 2 GB card capable of storing over 1 year of data
Particle Sizing	0.7 – 10 microns
Alarm Algorithm Settings	Indoor and Outdoor
Alarm Response Time	Configurable down to 1 second Recommend 30-60 seconds
Enclosure	Aluminum, IP66 Weatherproof
Triggered Collection	Integrated with DFU or C100 Sample Collector



Integrated Sample Collector Specifications

	DFU Collector	C100 Collector
Sampling Method	Dry collection	Wet or Dry collection
Power Consumption	60 Watts	60 Watts
Approximate Dimensions	3.5 x 3.0 inches (Height x Diameter)	4.5 x 5.5 inches (Height x Diameter)
Weight	1.3 lbs (0.6 kg)	3.0 lbs (1.4 kg)
Maximum Flow Rate	100 Liters/Minute	200 Liters/Minute
Particle Size Collection	1 to 10 microns	1 to 10 microns
Collection Media	Dry Sampling – polyester felt filters (47mm diameter, 1 micron)	Wet Sampling- Buffered rinse fluid provided in pre-measured vials + Dry Sampling option
Sample Recovery Method	Particle extraction from filter performed in vial with liquid buffer	Manual liquid rinse performed at collector – yields 6mL of liquid

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(三)Fido B2 生物危害性氣膠即時監控儀

IBAC IS NOW PART OF THE FIDO® FAMILY OF TRACE DETECTION & COLLECTION SYSTEMS

FIDO B2

FIDO® B2

REAL TIME BIOLOGICAL AEROSOL THREAT MONITOR

CONTINUOUSLY OPERATING MONITOR
EARLY WARNING OF BIOLOGICAL AEROSOL THREATS
AUTOMATIC SAMPLE CAPTURE

DETECT-TO-WARN SENSOR ARCHITECTURE

NEAR REAL TIME WARNING CAPABILITY

ALLOWS EARLY PROPHYLACTIC TREATMENT

MINIMIZES BUILDING CONTAMINATION VIA TRIGGERED HVAC MEASURES

FEATURES

Provides near real time warning capability for biological aerosol threats

Government validated with over 1.3 million hours of run time in relevant environments

Alert can automatically trigger a particulate sampler for subsequent identification

Unattended 24/7 operation without consumables

Complete self-diagnostic system

Easily integrated with most facility monitoring and control systems

Alert algorithms validated for both indoor and outdoor environments

OVERVIEW

The FIDO® B2, with IBAC technology, is a real-time continuously operating indoor or outdoor monitor that provides early warning of biological aerosol threats. The FIDO B2 facilitates the process of identifying bio-terror agents to allow timely containment, treatment and remediation. Monitors are designed to detect concentrated levels of biological aerosols. Possible agents released in a bio-threat attack can include bacterial spores (such as B. anthracis, which causes anthrax), bacteria (such as Y. pestis, which causes plague), viruses (such as smallpox) or toxins (such as ricin).

FIDO® B2, with IBAC technology, monitors can operate independently or as part of a network configuration to form the "first tier" of an airborne biological threat monitoring system. Communication and response can be managed through existing building control systems or an independent network.

In addition to providing real-time alerts to biological aerosol threats, the FIDO® B2, with IBAC technology, can trigger a secondary aerosol sample for subsequent analysis and identification. The C100™ modular tactical collector is designed for field collection of bioaerosols. The collector is based on proprietary rotating impactor technology and yields a 6 ml aqueous sample for field and laboratory analysis.

FLIR®

- Fido B2 生物危害性氣膠即時監控儀性能規格

FIDO® B2
REAL TIME BIOLOGICAL AEROSOL THREAT MONITOR

SPECIFICATIONS

Power Consumption	14 watts
Input Voltage	100 to 240 VAC
Case Dimensions	12 in x 8 in x 11 in (30 cm x 20 cm x 28 cm)
Weight	8.5 lbs (3.9 kg)
Communication	Ethernet, RS-232
Air Flow Rate	3.8 liters/minute
Operating Temperature	-5 to +125°F (-20 to +50 °C)
Storage Temperature	-40 to +160°F (-40 to +70 °C)
Operating Time	24 hours/day, continuously
Outputs	Particle data, bio-alarm, fault
Data Storage	Expandable internal MicroSD memory card
Aerosol Sizing	0.7 microns and larger
Maximum Aerosol Count Rate	25,000 particles/sec (500,000 particles/liter)
Measurement Frequency	Configurable down to 1/sec
Response Time	30 to 60 seconds
Enclosure	Aluminum, IP 66, weatherproof
Mounting	Mounts on vertical surfaces, horizontal surfaces or within secondary enclosure
Triggered Collection	Compatible with C100, BioXC™ and other triggered samplers

附錄六、法國 Proengin 儀器及性能相關資料(目前國內無代理商)

(一) MAB 野戰型生物即時預警系統

MAB

MAB
Biological alarm monitor
Reconnaissance and critical areas
surveillance operation

Description

Raises a real time alarm on all change in the biological background (bacteria, toxins, viruses)

Continuous measurement

Adapted to harsh environmental conditions

RS485 data link, remote controllable

Detection

Selective sampling (particles from 2 to 10 microns), chemical analyzis of each particle (flame spectrometry)

Real time analyzis of chemical elements ratio, flame light intensity and number of particles.

Alarm data: light and sound signal, data recording and transfer to either remote control box or security network, ability to trigger a biosampler

Sampling flow rate: 16 Liters per minute

Short response time: max 1 minute (threshold level), commonly 10 to 15 seconds

PROENGIN
Chemical and biological detection systems

- MAB 野戰型生物即時預警系統規格

MAB

Image courtesy: JP Lagiewski

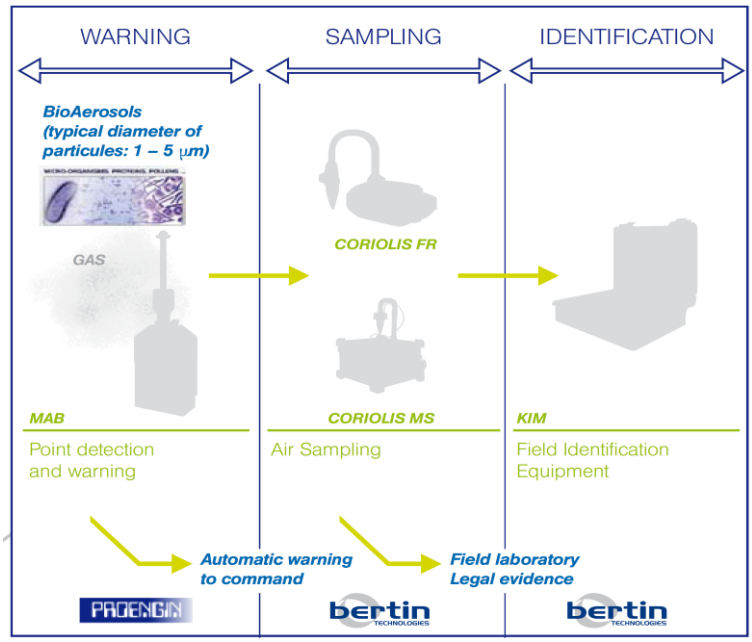
Characteristics (mm, kg)

Length	Width	Height	Weight
300 mm	160 mm	470 mm (detection module) 895 mm (including air inlet)	14 kg

Electrical characteristics

Electrical consumption: max 30W (at start), 15W (under stabilized operation)

- Proengin MAB 野戰型生物即時預警系統原始發展構想示意圖

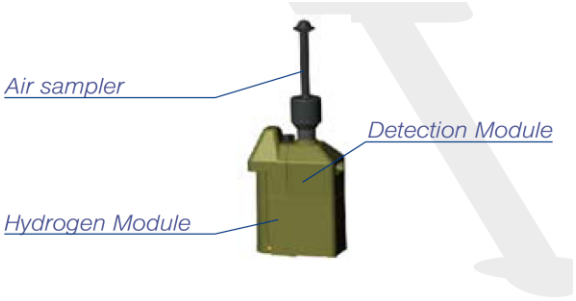


- MAB 野戰型生物即時預警系統性能規格

GENERAL DESCRIPTION

MAB is a one piece ruggedized system that can be deployed in a few minutes anywhere on a battlefield. It can be connected either to a display box for a direct view of alarms, or to a laptop (through a network) to view alarms and data about the categories of particles, and/or to a bio sampler (ideally the ***Coriolis*® *MS***).

MAB analyzes the particles in the air 83 times per second and therefore gives a continuous monitoring of the type of particles present in the air. Alarm thresholds are preset in terms of number of particles, or rapidity of concentration increase. These thresholds can be adjusted by the user to cope with the type of environment.
It requires low power (max.45W) and hydrogen. Hydrogen can be supplied by cylinders or an electrolyser.



SPECIFICATIONS

Specifications	*MAB*
Size	300mm x 160mm x 450mm (11.8" x 6.3" x 17.7")
Height	800 mm (31.5")
Weight	13 kg
Temperatures	-20°C to +50°C (-4°F to +122°F) (operation) -39°C to +55°C (-38.2°F to +131°F) (storage)
Lifespan	up to 10 days (refillable hydrogen cylinder included in the appliance)
Power supply	19-32VDC or 110-220 VAC
Remote control	can be remote controlled
Remote data	by RS 485 outlet
Response time	less than 1 minute

PRINCIPLE

The ***MAB*** is based on flame spectrophotometry technology. It operates by analysing the light spectrum of a flame of hydrogen. ***MAB*** analyses the chemical composition of each particle and measures their relative content of potassium, sodium, as well other elements. Particles are then categorized by their chemical signature and their concentration.

QUALIFICATION

Reports available from international independent and recognized laboratories on demand.

附錄七、交通部鐵路管理局函覆同意本所赴板橋車站進行採樣之公文

正 本

發文方式：紙本遞送

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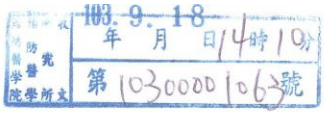

交通部臺灣鐵路管理局　函

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附件：

主旨：貴所承辦疾病管制署委託「空氣中生物性危害物質之監測及基礎值建立」研究計畫，希於本局板橋站採集空氣樣本1案，以不影響旅客安全及動線原則下，同意於地下1樓非付費區配合辦理，相關細節請逕洽該站（02-89691036），請查照。

說明：

一、復貴所103年9月10日國院預防字第1030000346號函。

二、副知臺北運務段協助板橋站配合辦理，並檢附原函影本1份。

正本：國防醫學院預防醫學研究所
副本：本局臺北運務段、板橋站（均含附件）

局長周永暉

本案依分層負責規定授權業務主管決行