出國報告（出國類別：其他）

參加 2007 年 A&WMA 研討會暨國際環保工業技術展覽會

服務機關：行政院環境保護署
姓名職稱：處長 楊慶熙等 2 人
派赴國家：美國
出國期間：96 年 6 月 24 日至 96 年 7 月 1 日
報告日期：96 年 7 月 19 日

摘要

A&WMA 研討會暨國際環保工業技術展覽會（Air and Waste Management Association's 100th Annual Conference and Exhibition），爲環保界最重要之國際研討會暨展覽會之一，每年在美國各大城市輪流舉辦，已成功舉辦 99 屆，今年第 100 屆以最盛大的方式在美國賓州匹茲堡市舉行，該協會在本次研討會中安排論文發表、專題演講及環保工業技術展覽會。

本次研討會自 6 月 26 日至 6 月 29 日在 David L. Lawrence 會議中心舉行，研討會規劃計有 16 項主題，分別爲褐色場址（Brownsfields）、核能（Nuclear Energy）、新污染源評鑑（NSR Reform）、聯邦空氣清淨法「許可證計畫」（Title V Permitting Compliance）、污染預防與廢棄物管理（Pollution Prevention and Waste Management）、周界與污染源之量測（Ambient and Source Measurements）、國際研究焦點（Focus on International Studies）、跨國界空氣品質議題與計畫（Trans-Boundary Air Quality Issues and Programs）、環境風險評估與管理（Environmental Risk Assessment and Risk Management）、光學及遙測（Optical/Remote Sensing）、臭氧、粒狀物及區域性煙霧（Ozone, Particulate Matter, and Regional Haze）、室內空氣品質議題（Indoor Air Quality Issues）、最大限度能達到的控制技術及更新（MACT Standards and Updates）、運輸議題（Transportation Issues）、環境協調議題（Environmental Compliance Issues）及全球氣候變遷環境議題（Global Climate Change Environmental Issues）。

本署計有三篇論文在此次研討會中發表，一爲「廢棄物 E 化與 M 化管理」，二爲「零廢棄政策」，三爲「運用 OP-FTIR/AERMOD 評估製藥廠臭味負荷之研究」，說明我國現階段對於廢棄物管理之策略與現況，以及運用遙測技術搭配污染擴散模式調查臭味污染案件。

在環保工業技術展覽會部分，其展覽期間爲 6 月 26 日至 6 月 28 日，展覽各種

空氣污染監測儀器、空氣污染泥廢棄物處理設備、污染防治技術、調查研究成果等；爲因應國際環保潮流與趨勢，我國目前積極設置「環保科技園區」，推動綠色產業發展，以建立循環型社會並開創全球化環保市場，本署亦在會場中設攤展示我國花蓮、桃園、台南與高雄 4 個環保科技園區設置理念及招商，台灣推出之環保科技園區，以「產業共生、資源共享、資訊互通、風險分攤」爲規劃藍圖，開創「高級資源再生技術」、「高級環保技術」及「生態化產業」等三大產業爲發展主軸，藉由此國際研討會之展覽機會，積極尋求世界各地之高級環保科技共同合作，營造低污染、高附加價值並兼顧生產、生活、生態，三生一體之環保示範園區，以促使企業永續發展。

在最後參訪卡內基美隆大學（Carnegie Mellon University），特別前往參觀該校綠建築，其包含下列幾點特色：a.最大化的自然調節及提供大化的個別空間進入自然環境（Maximize Natural Conditioning & Maximize Individual Access to the Natural Environment），如自然通風與日照；b.最佳的工程設計減少材料的使用（Optimize Design/Engineering to Reduce Material Use），如使用回收材料、低廢棄物的製造程序；c.零廢棄的快速建造程序（Maximize Speed of Constructability, No-waste Construction Processes）；d.建築材料完整性及永續使用（Maximize Integrity and Material Sustainability），如套件或模組組裝；在參訪過程中 Davidson & Loftness 兩位教授詳細的介紹及說明，讓參訪人員感受到該校之用心，也增進參訪成員對綠建築之瞭解。

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壹、 目的

空氣及廢棄物管理協會（Air and Waste Management Association）可追溯在 1907 年 6 月於美國 Milwaukee 召開市區煙害防治會議開始，迄今已屆 100 週年，從期初由美國及加拿大部分地區的工程人員，集會研商並分享針對市區煙霧公害之防治對策及技術，發展至今成為專業管理協會，該協會除定期召開國際性研討會，提供全世界在空氣污染及廢棄物管理之專業管理議題進行探討及交流，並藉由專業期刊發表各種研究成果，以鼓舞有關空氣污染及廢棄物管理議題或各種專業技術之研究。

本次研討會暨展覽會自 6 月 26 日至 6 月 29 日在美國賓州匹茲堡市 David L. Lawrence 會議中心舉行，會議期間安排各項專業議題論文發表及研討，並在會議中心廣場舉辦各種環保專業展覽，包括污染防治器材、監測器材、防治技術及管理成果，本署亦在會場中設攤展示我國花蓮、桃園、台南與高雄 4 個環保科技園區設置理念及招商。本次參加研討會目的有三項，第一項目的為藉由論文發表說明我國針對空氣污染及廢棄物管理之成果，讓各國有機會瞭解台灣針對環境保護之努力成果，在本次研討會中本署計有三篇論文在此次研討會中發表，一為「廢棄物 E 化與 M 化管理（The e-Revolution and Mobilization of Waste Management in Taiwan）」，二為「零廢棄政策（Zero Waste Policy for Municipal Solid Waste in Taiwan）」，三為「運用 OP-FTIR/AERMOD 評估製藥廠臭味負荷之研究（Odor Load Estimation for A Pharmaceutical Plant by OP-FTIR/ AERMOD）」，前二篇說明我國現階段對於廢棄物管理之策略與現況，第三篇說明運用遙測技術搭配污染擴散模式調查臭味污染案件。

第二項目的為藉由此機會觀摩各種最新環保技術與管理趨勢，促進環保技術交流及人員交流，以增進我國在世界之能見度。第三項目的為展示我國環保科技園區規劃理念及積極招商尋求世界各地之高級環保科技共同合作，以達到營造低污染、高附加價值並兼顧生產、生活、生態，三生一體之環保示範園區。

貳、過程

本次出國參加研討會及環保工業技術展覽會期間爲 96 年 6 月 24 日至 7 月 1 日共計 8 日，參與成員及工作任務如表一，相關行程包括參加研討會論文發表、參與環保工業技術展覽會及參訪卡內基美隆大學（Carnegie Mellon University），詳細行程如表二所示，以下將就出席研討會及參訪行程進行說明。

表一　參與成員名單及任務

姓名	服務單位/職稱	工作任務
楊慶熙	行政院環境保護署管制考核及糾紛處理處處長	出席研討會及論文發表
張文興	行政院環境保護署環境檢驗所研究員	出席研討會及論文發表

表二　出席研討會行程

日期	地點	行程
6 月 24 日 (星期日)	台北→匹茲堡	啓程(搭機前往美國匹茲堡國際機場)
6 月 25 日 (星期一)	匹茲堡 David L. Lawrence Convention Center	2007 A&WMA's 100th Annual Conference & Exhibition 進駐展場整備及註冊
6 月 26 日 (星期二)	匹茲堡 David L. Lawrence Convention Center	1. 楊處長慶熙發表「零廢棄政策（Zero Waste Policy for Municipal Solid Waste in Taiwan）」論文 2. 環保科技園區招商展覽
6 月 27 日 (星期三)	匹茲堡 David L. Lawrence Convention Center	1. 楊處長慶熙發表「廢棄物 E 化與 M 化管理（The e-Revolution and Mobilization of Waste Management in Taiwan）」論文 2. 張文興研究員發表「運用 OP-FTIR/AERMOD 評估製藥廠臭味負荷之研究（Odor Load Estimation for A Pharmaceutical Plant by OP-FTIR/ AERMOD）」論文

		3. 環保科技園區招商展覽
6 月 28 日 (星期四)	匹茲堡 David L. Lawrence Convention Center	1. 環保科技園區招商展覽 2. 下午展場結束展覽
6 月 29 日 (星期五)	匹茲堡	參訪卡內基美隆大學（Carnegie Mellon University）
6 月 30 日至 7 月 1 日 (星期六、日)	匹茲堡→台北	返程

一、研討會論文發表

本次研討會自 6 月 26 日至 6 月 29 日在 David L. Lawrence 會議中心舉行，在研討會上發表的論文計有 310 篇，出自台灣各大學院校或研究機構或政府部門之篇數高達 61 篇，研討會規劃有 16 項主題，分別爲褐色場址（Brownsfields）、核能（Nuclear Energy）、新污染源評鑑（NSR Reform）、聯邦空氣清淨法「許可證計畫」（Title V Permitting Compliance）、污染預防與廢棄物管理（Pollution Prevention and Waste Management）、周界與污染源之量測（Ambient and Source Measurements）、國際研究焦點（Focus on International Studies）、跨國界空氣品質議題與計畫（Trans-Boundary Air Quality Issues and Programs）、環境風險評估與管理（Environmental Risk Assessment and Risk Management）、光學及遙測（Optical/Remote Sensing）、臭氧、粒狀物及區域性煙霧（Ozone, Particulate Matter, and Regional Haze）、室內空氣品質議題（Indoor Air Quality Issues）、最大限度能達到的控制技術及更新（MACT Standards and Updates）、運輸議題（Transportation Issues）、環境協調議題（Environmental Compliance Issues）及全球氣候變遷環境議題（Global Climate Change Environmental Issues）。

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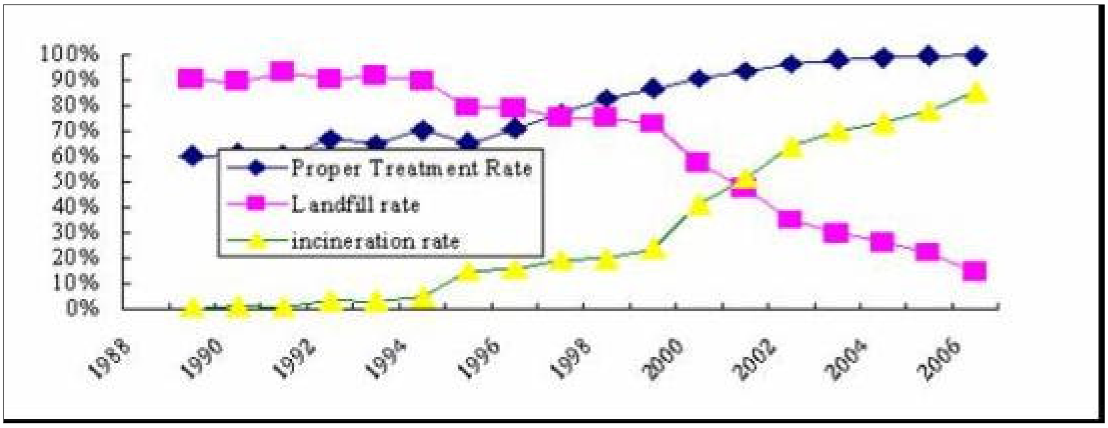
(一) 零廢棄政策（Zero Waste Policy for Municipal Solid Waste in Taiwan）

本篇論文由本署楊慶熙處長於 6 月 26 日下午發表，其簡報首先回顧台灣都市固體廢棄物處理歷史，在 1984 年以前並沒有正確適當的處理方式，自 1984 年起方闢設衛生掩埋場，當年的垃圾妥善處理率僅有 2.4%，而在 1991 年起方開始闢建固體廢棄物焚化爐，至 2006 年已有 22 座焚化爐闢建完工及營運，每天可處理 18000 噸廢棄物，

並利用產生之廢熱發電，將垃圾轉化爲電力，而且已逐漸從掩埋方式轉換以焚化方式處理廢棄物，截至 2006 年已有 85.2%以焚化方式處理，都市固體廢棄物妥善處理率已高達 99.8%。台灣都市固體廢棄物目前處理現況，在興建固體廢棄物焚化爐及衛生掩埋場後，已有效減少垃圾露天棄置問題，但是在民眾對環境品質要求之意識日益高漲，針對增設固體廢棄物處理設施之用地取得，是愈加困難。環保團體及民意代表紛紛要求政府應該採取有效管制策略，以減少廢棄物產出及減少廢棄物焚化及掩埋處理，因此，在參考其他已開發國家所施行之零廢棄願景，本署在 2003 年開始施行零廢棄政策，爲資源永續利用開啓里程碑。圖一顯示在 1988 年以後廢棄物掩埋、焚化及妥善處理趨勢圖。

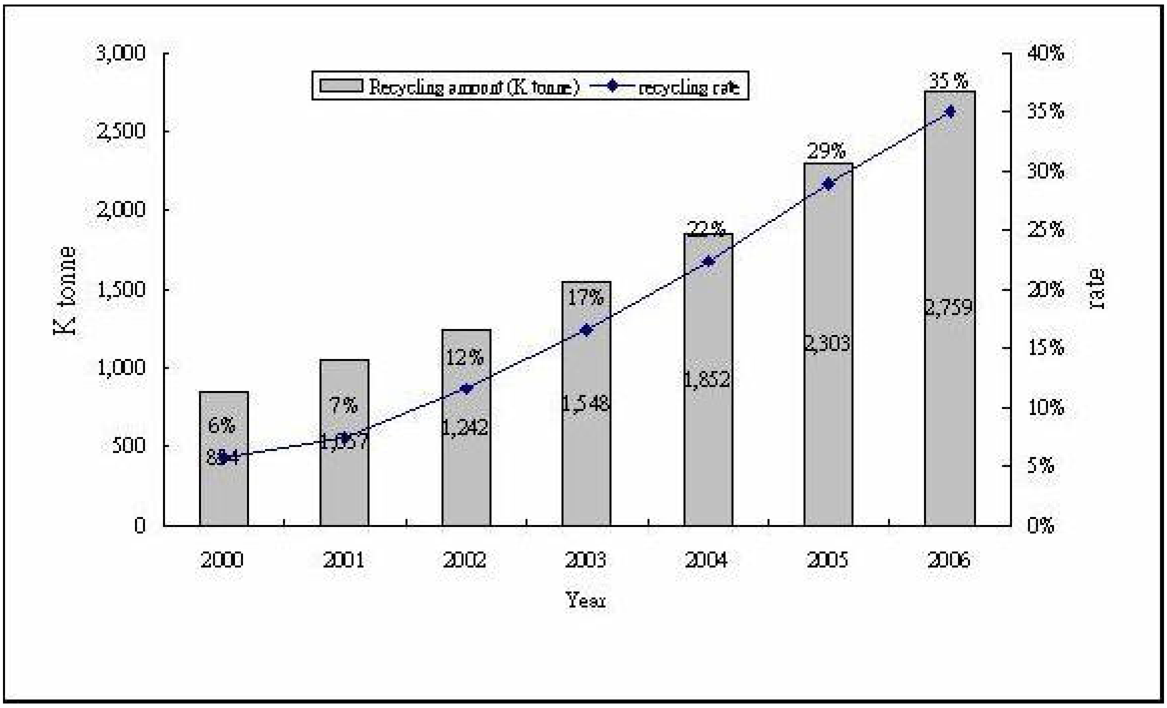


圖一　都市固體廢棄物掩埋、焚化及妥善處理率

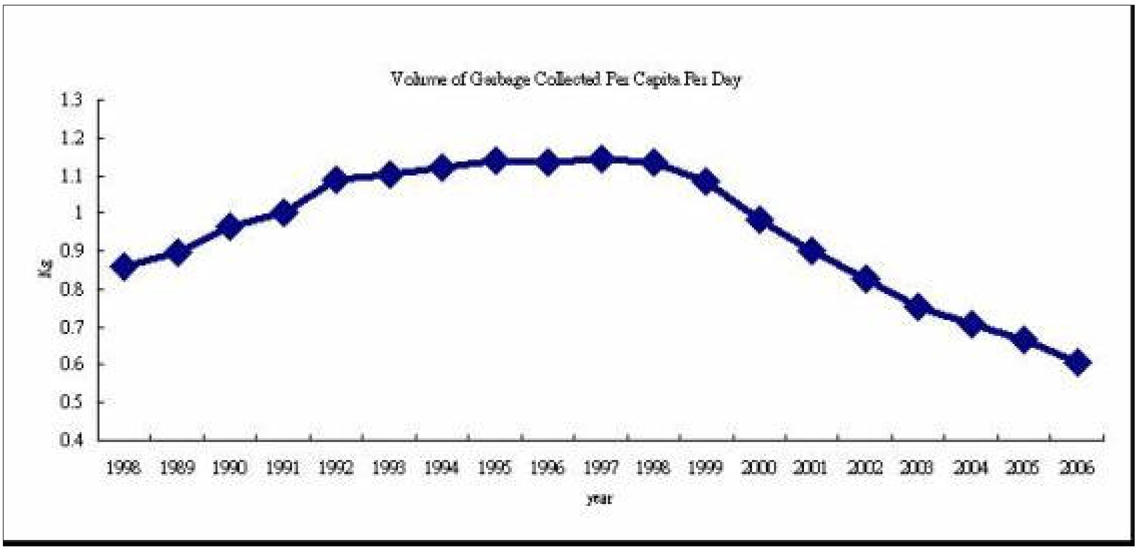
在 1997 年規範製造業及進口商之回收責任，本署公告 15 種 32 項必須回收再利用物品，如容器、電池、汽機車、輪胎、潤滑油、家電、電腦、印表機、日光燈等，而且立法強制徵收回收基金，並運用在補助及促進回收工作之執行。而此回收基金系統，係建置在四合一的方案下進行，結合廢棄物產出者—社區居民、民間回收業者、地方政府及回收基金會，形成有效回收體制，圖二所示爲四合一方案及基金運作系統圖。

圖二　四合一方案及基金運作架構

圖三顯示藉由強制回收政策及四合一方案之施行，資源物質回收從 2000 年的 834 公噸，佔廢棄物產生量 6%至 2006 年的 1759 公噸，佔廢棄物產生量 35%，而廢棄物平均每日每人的收集量，從 1997 年最高量 1.14 kg 下降至 2006 年 0.61 kg，如圖四所示，顯見回收之成效良好。



圖三　2000~2006 年廢棄物資源回收率



圖四　都市固體廢棄物每日每人收集量

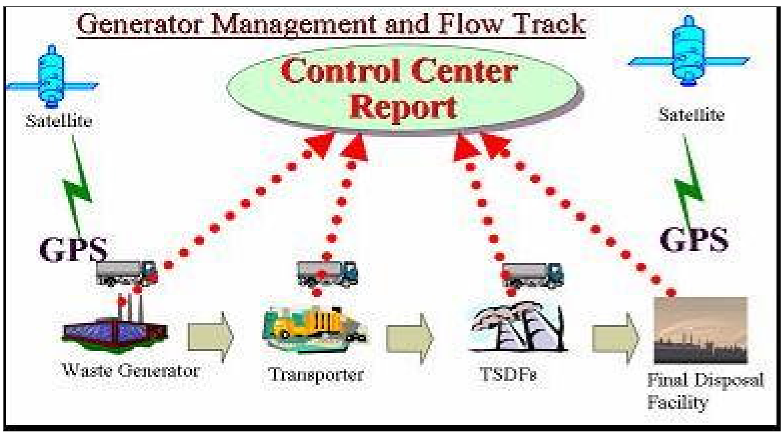
本署在 2003 年開始施行零廢棄政策，其目標是要達到永續發展的社會，並回應日漸受到關切的焚化爐及衛生掩埋場所造成之環境影響及改變管末之管理方式，變更爲源頭減量、廢棄物回收、再利用及綠色消費之管理策略，都市固體廢棄物減量目標以 2001 年之廢棄物量爲參考基準，2007 年設定減量目標爲 25%，2011 年設定目標爲 40%，2020 年設定減量目標爲 75%，並在 2007 年以後限制僅偏遠地區方可採掩埋方式處理廢棄物。

與會人員在聆聽本署楊慶熙處長簡報我國零廢棄政策後，引起諸多共鳴，咸認爲此政策對於營造生態城市（eco-town）有相當助益，尤其針對四合一回收體系中民眾及社區的配合、回收再利機制中的廢傢俱再生製造及綠色消費的限制產品過度包裝措施，對於台灣有此經驗及成效均感到不可思議與佩服。

(二)　廢棄物 E 化與 M 化管理（The e-Revolution and Mobilization of Waste Management in Taiwan）

本篇論文由本署楊慶熙處長於 6 月 27 日上午發表，其簡報首先介紹台灣環境負荷，目前登記有案的工廠約有 90000 家，醫療機構將近 20000 家，以及每年將近 20000 處的營建工地，在扮演著廢棄物製造者的角色，每年約產出 2600 萬公噸的廢棄物在僅有 36000 平方公里的台灣土地上，而截至目前已發現 170 處嚴重污染的非法棄置場址。

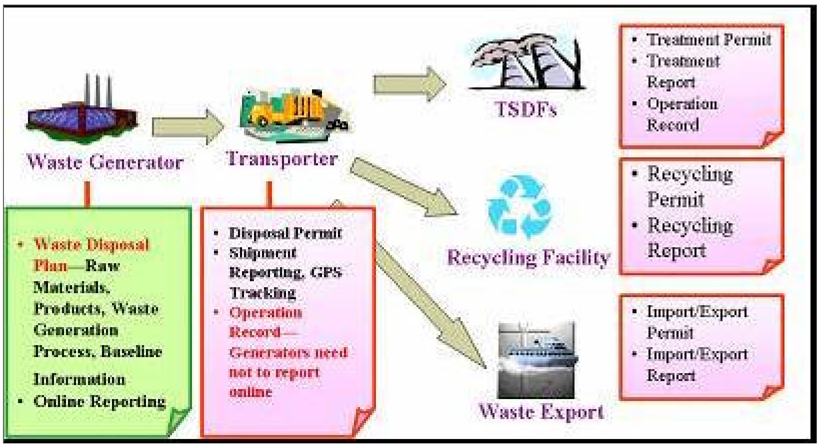
在 2000 年本署成立事業廢棄物管制中心，藉由電子傳輸及衛星定位追蹤工具，整合事業廢棄物之管理，截至 2006 年已公告指定約 20000 家的事業單位，必須上網申報其事業廢棄物清除及處理流向，申報之廢棄物量累計約有 14,600,000 百萬噸，回收或再利用佔 74.27%，清除處理約佔 14.72%，暫存於事業單位約佔 2.90%，自行處理約佔 7.65%，輸出約佔 0.45%。台灣針對事業廢棄物的管制策略為強化事業廢棄物源頭管理、流向申報管制及稽查取締，分別說明如后，首先對事業廢棄物管制採「從搖籃到墳墓」的管制策略，要求事業廢棄物產生者、清除機構、處理機構及最終處理機構，藉由電子傳輸登錄全國事業廢棄物管制系統申報廢棄物清理情形，並藉由衛星定位系統追蹤廢棄物清運情形，圖五所示事業廢棄物流向管制流程示意圖。



圖五　事業廢棄物流向管制流程

其次要求從事業廢棄物產生者至最終處置者，必須依規定取得許可及申報相關清理

資料，如事業廢棄物產生者必須於設立營運前申報事業廢棄物清理計畫書，並於取得核可後始得營運，並應上線至全國事業廢棄物管制系統申報其廢棄物清理情形相關資料；事業廢棄物清除業者亦必須於取得許可後始得營運，其清運車輛必須安裝衛星定位系統以追蹤清運車輛流向，並應定期申報其營運紀錄；而事業廢棄物可經由中間處理、或回收再利用、或輸出境外處理，其均需於取得許可後始得為之，且這些業者均應定期申報其營運紀錄，其管制內容如圖六所示。



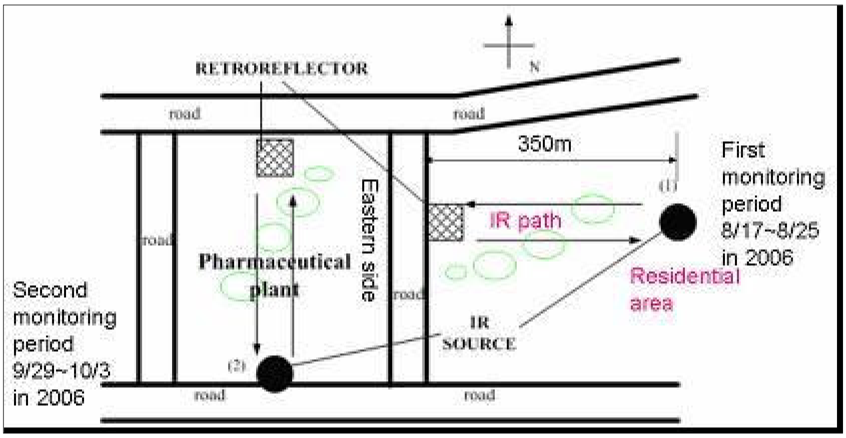
圖六　事業廢棄物流向管制內容

在針對事業廢棄物製造者，採事前許可管制措施，要求公告指定業者於設立前提報事業廢棄物清理計畫書，並於營運後上線申報廢棄物清理流向，並由公部門透過現場稽核與檢查廢棄物清理情形，督促事業單位妥善處理事業廢棄物，且透過網際網路申報系統線上分析、勾稽比對廢棄物清理內容及流向，從事業廢棄物產生者至最終處置業者，地方政府至環保署，均能確實掌握廢棄物清理流向，亦符合便民與環境管理之需求。

(三)　運用 OP-FTIR/AERMOD 評估製藥廠臭味負荷之研究（Odor Load Estimation for A Pharmaceutical Plant by OP-FTIR/ AERMOD）

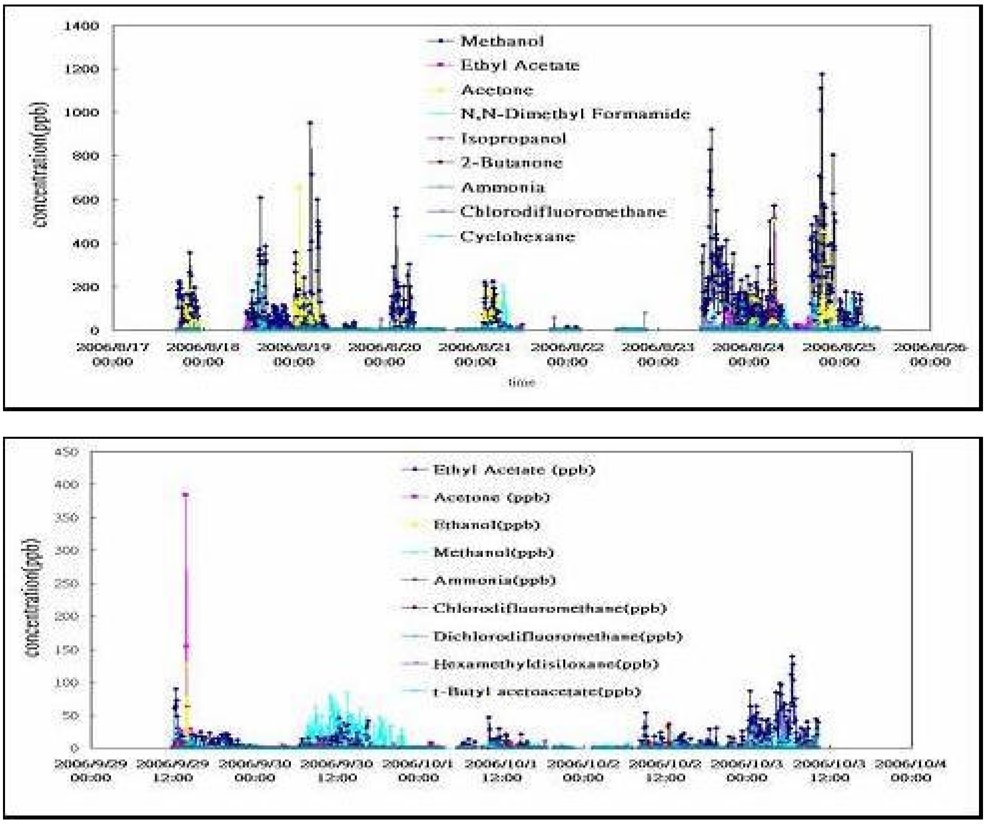
本篇論文由本署張文興研究員於 6 月 27 日下午發表，其簡報內容為運用遙測技術搭配污染擴散模式調查臭味污染事件，本研究場址係位於台灣北部的工業區，本次污染事件是發生在 2006 年，在該工業區附近居民經常聞到令人不愉快的臭味，但是居民並不知道該臭味是從何而來，因此透過各種申訴管道，甚至透過新聞媒體要求政府環保部門應儘速查明及遏止此污染事件持續發生，所以研究人員運用開徑式傅立葉轉換紅外光光譜儀(Open-path Fourier transform infrared, OP-FTIR)搭配三點比較式嗅袋法測定臭味指數（odor index）及 AERMOD 空氣擴散模式模擬臭味及污染擴散情形，以瞭解臭味影響區域。

根據民眾陳情反映之地點，研究小組將 OP-FTIR 置放於住家頂樓，反射鏡則置放於工業區邊緣之工廠頂樓，距離約 350 公尺，監測期間為 8 月 17 日至 25 日，根據所測得污染物資料及追查其來源，研究小組於 9 月 29 日至 10 月 3 日將 OP-FTIR 置放於鄰近的製藥工廠圍牆旁，反射鏡則置放於圍牆另一端，如圖七所示。



圖七　OP-FTIR 監測位置

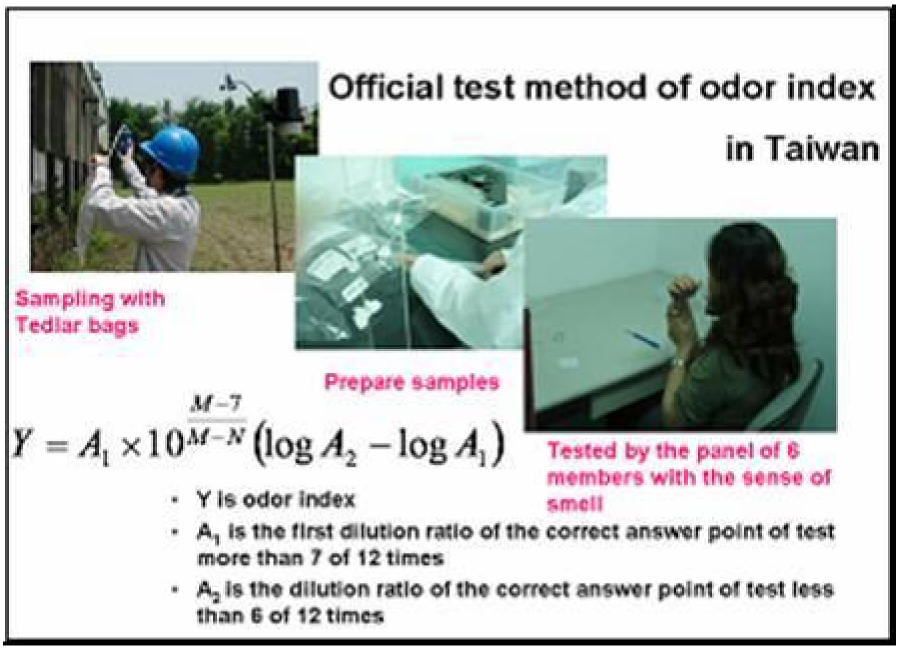
第一次 OP-FTIR 監測得到 1642 組數據，計測得 9 種污染物，分別爲 methanol、ethyl acetate、acetone、N, N-dimethyl formamide、isopropanol、2-butanone、ammonia、chlorodifluoromethane、cyclohexane，第二次 OP-FTIR 監測得到 1073 組數據，亦測得 9 種污染物，分別爲 methanol、ethyl acetate、acetone、ammonia、chlorodifluoromethane、ethanol、dichlorodifluoromethane、hexamethyldisiloxane、t-Butyl acetoacetate，經比對分析得到在此區域民眾常聞到之臭味爲來自鄰近之製藥工廠，且 ethyl acetate、acetone 爲主要污染物，該 2 次監測期間及污染物變化如圖八所示。



圖八　監測期間污染物變化

在運用 OP-FTIR 監測期間，同時於製藥工廠及其下風處採集臭氣，以三點比較式嗅袋法測定臭味指數（odor index），圖九所示我國目前官方臭味指數（odor index）測定程序，臭味指數測定 4 組計 12 點次，僅有 1 點未超過目前住宅區臭味標準 10，其相

關數據資料如表三所示。



圖九 臭味指數測定程序

表三　臭味指數測定資料

Sampling set	Odor index	Upwind position coordinate a (X , Y)	Odor index	Downwind Position Coordinate b (X , Y)	Odor index	Downwind Position Coordinate c (X, Y)
1	80	291448, 2763585	58	291349, 2763432	48	291225, 2763345
2	67	291458, 2763484	63	291305, 2763389	48	291241, 2763299
3	78	291309, 2763393	63	291253, 2763330	63	291194, 2763302
4	30	291107, 2763279	14.5	291007, 2763228	＜10	290855, 2763129

在本研究中定義臭味強度（odor intensity）污染物的濃度值除以其臭味閾值濃度，其公式如下所示。

$$I = \frac{C_1}{C_0} \quad > 1, \text{ be smelled}$$

I is the odor intensity

C_1 is the pollutant concentration

C_0 is the odor threshold concentration

因此，本研究利用 OP-FTIR 監測污染物濃度及上述臭味強度公式轉換爲污染物之臭氣強度，再與實測之臭味指數進行回歸分析，得到一線性方程式，如下所示，其 R^2=0.9978，顯示其有良好相關性。

$$Y = 7.56 + 7.26X_1 + 5.86X_2$$

Where

Y = odor index

X_1= ethyl acetate odor intensity

X_2= acetone odor intensity

R^2 = 0.9978

在 AERMOD 模式部分，半衰期爲其模擬污染物擴散重要參數，而臭氣其可能由 1 種或以上之污染物混合產生，因此無法就個別監測到之污染進行半衰期探討，所以研究小組以臭味上下風處之濃度，以風速及距離回歸分析得到四組指數方程式，如表四所示。

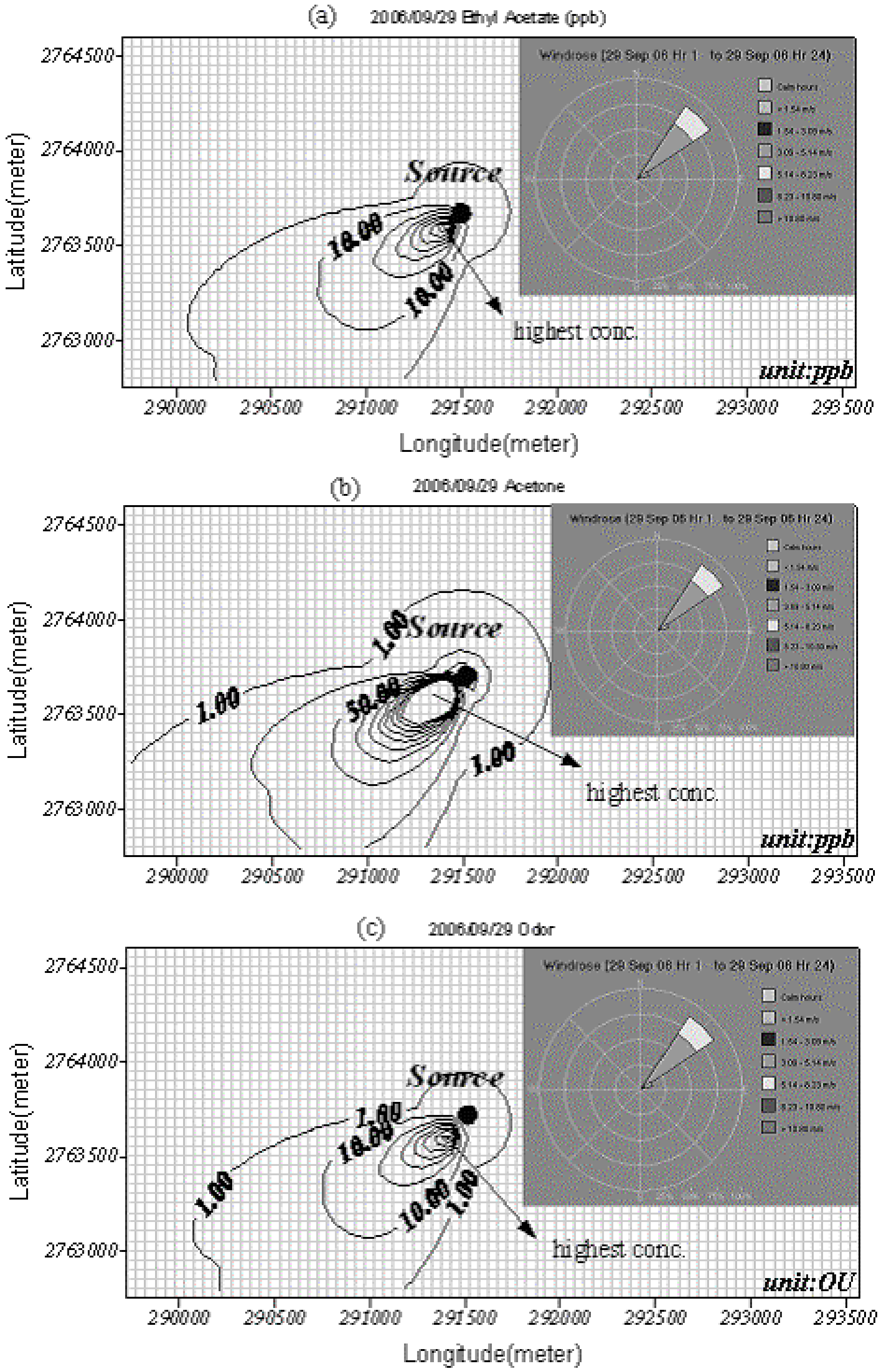
表四　半衰期指數方程式

a,b,c odor index	Regression equation	R^2	half-life (second)
80,58,48	y = 78.977e-0.0071x	0.9909	95.81
67,63,48	y = 68.813e-0.0034x	0.9546	211.72
78,63,63	y = 73.695e-0.0037x	0.6013	171.99
30,14.5,<10	y = 24.774e-0.0111x	0.8207	45.20

Y is half-life time，X is windspeed

最後運用所得之半衰期資料、污染物排放率、氣象資料及污染源之座標資料輸入 AERMOD 模式中模擬污染物及臭味擴散情形，圖十顯示以 ethyl acetate、acetone 及臭味之擴散模擬圖，尤以臭味擴散模擬圖，研究小組標定法規住宅區臭氣標準 10 之等濃度線，在其內之區域將受到明顯之影響。

藉由本研究方法可利用 OP-FTIR 快速監測及追蹤污染來源，並有效運用 AERMOD 模式模擬預測污染物及臭味擴散情形，以評估該區域之臭味負荷，提供廠商做為改善之參考，亦提供政府部門最為有效之管制依據。對於本篇論文與會研討之國際友人，均表示以 OP-FTIR、AERMOD 結合台灣當地之官方臭味指數測定方法，調查追蹤及模擬污染擴散情形，以評估其影響程度，係一實用及快速之方法。



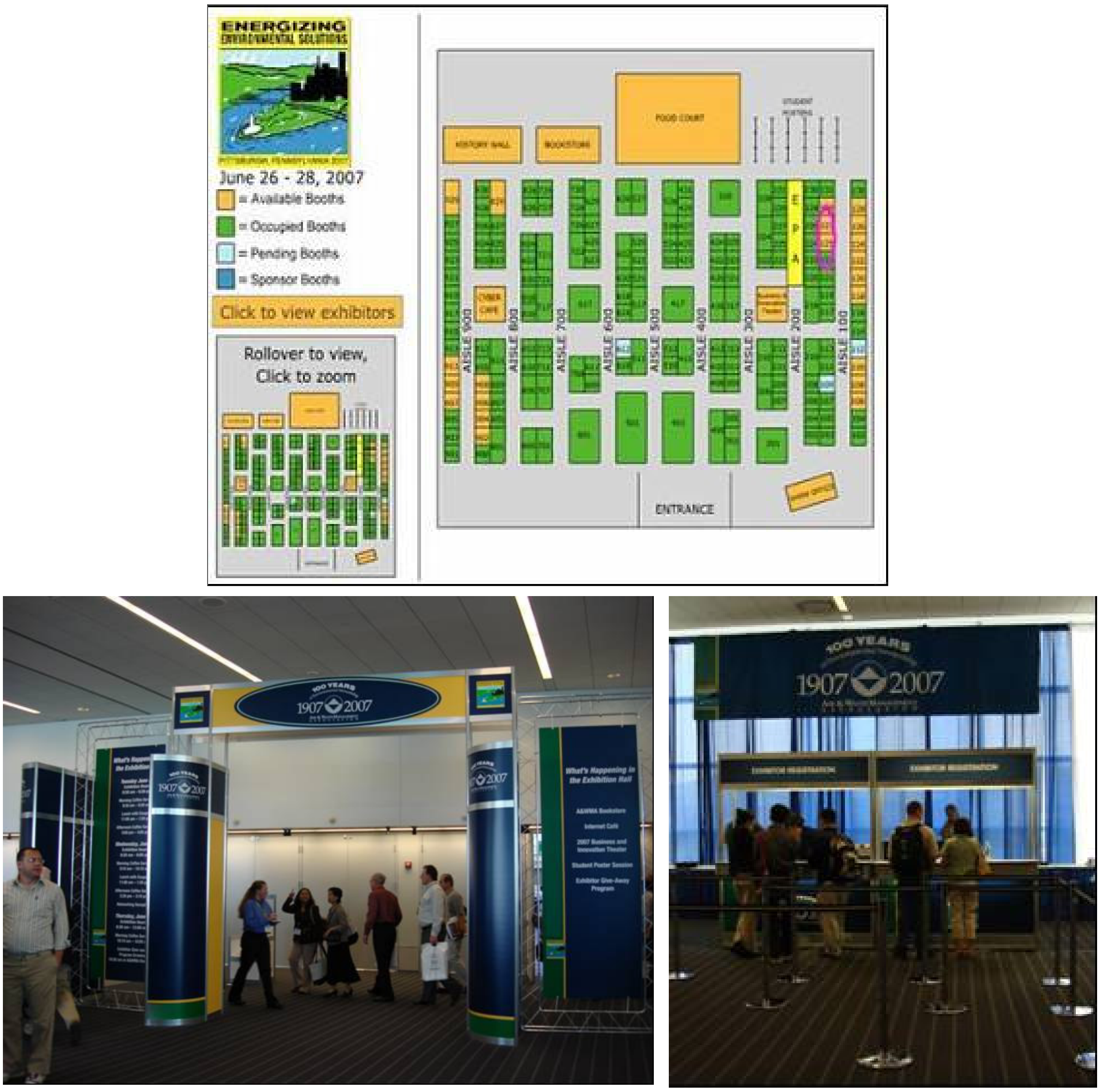
圖十　ethyl acetate、acetone 及臭味指數之擴散模擬

二、環保科技園區招商展覽

2007 年 A&WMA 第 100 屆研討會暨國際環保工業技術展覽會（Air and Waste Management Association's 100th Annual Conference and Exhibition），為環保界最重要之國際研討會暨展覽會之一，每年在美國各大城市輪流舉辦，已成功舉辦 99 屆，今年第 100 屆以最盛大的方式在美國賓州匹茲堡市 David L. Lawrence Convention Center 的三樓展覽廳舉行，該會議中心是全世界第一個被驗證之綠色會議中心。在此難得機會，本署積極安排參與國際環保工業技術展覽會，展示我國為因應國際環保潮流與趨勢，積極規劃設置「環保科技園區」之理念，啓動綠色產業發展及建立循環型社會，以達到開創全球化環保市場之目標。

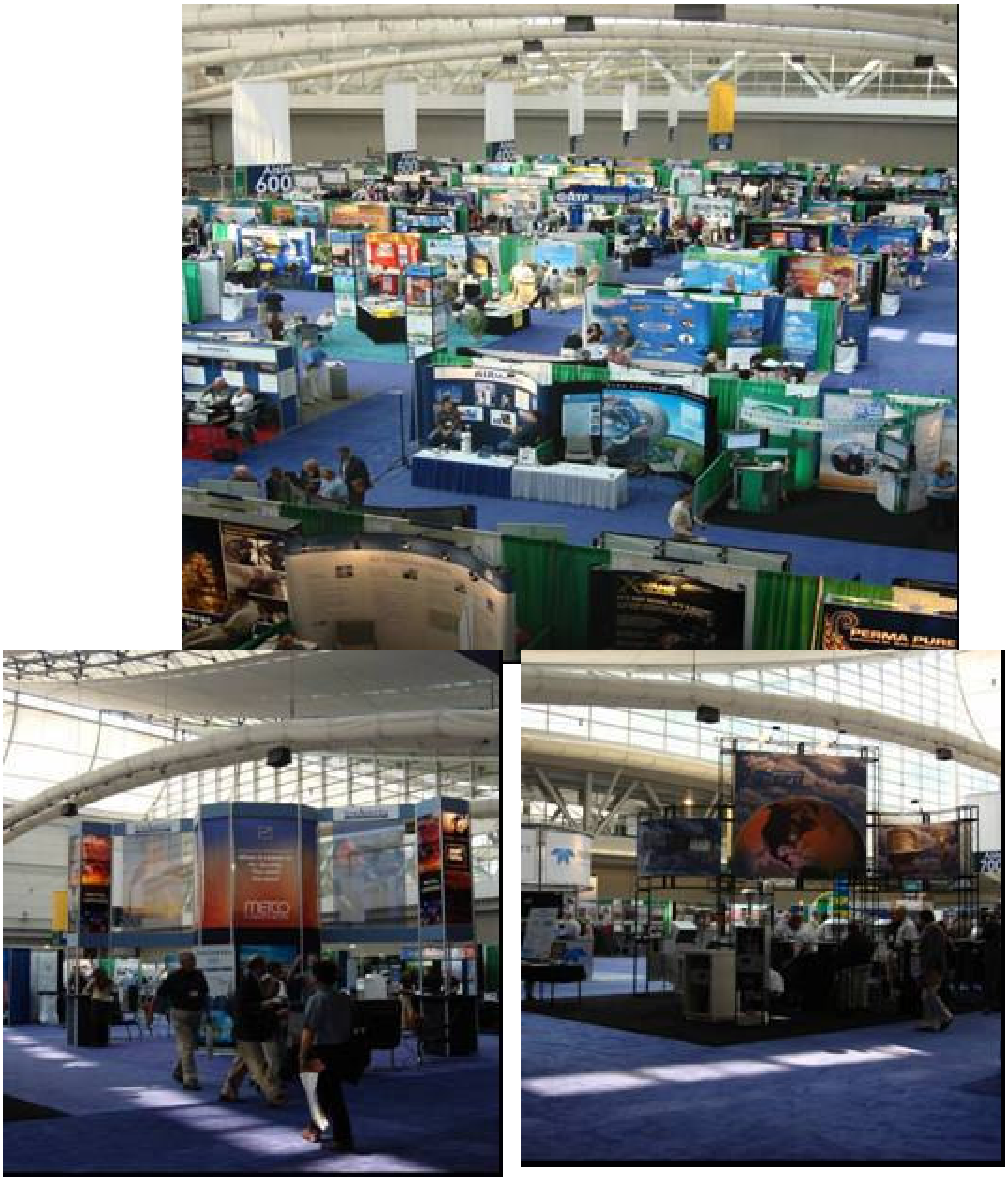
我國推出之環保科技園區，係以「產業共生、資源共享、資訊互通、風險分攤」為規劃藍圖，開創「高級資源再生技術」、「高級環保技術」及「生態化產業」等三大產業發展主軸，積極尋求世界各地之高級環保科技共同合作，整合國內外環保產業技術，營造低污染、高附加價值並兼顧生產、生活、生態，三生一體之環保示範園區，以投資台灣佈局全世界的理念，促使產業永續發展。

本次國際環保工業技術展覽會展覽日期為 96 年 6 月 26 日至 28 日，本署設置攤位號碼為 127、129 號，攤位配置如圖十一所示，係委託由工業技術研究院負責參展作業之規劃執行，並邀請台南與高雄環保科技園區人員共同參與展覽及招商，並由工業技術研究院及環保科技園區人員於 6 月 25 日進場整備佈置。在展覽過程中，參觀人員對我國規劃設置「環保科技園區」之理念均表示認同與肯定，並咸認為以台灣島嶼型國家，在有限自然資源及環境敏感度高之前題下，以資源零廢棄、污染零排放及永續利用之生態工業發展策略，在考量經濟利益發展前題下，兼顧環境保護與社會福利，使工業系統不再成為一種污染源，以獲得環境、經濟及社會之三重盈餘，以達到循環型環境，是我國促進生態工業發展及永續發展之最佳策略。圖十二所示為會場報到及註冊情形。



圖十二　會場報到及註冊

圖十三為展場實況配置圖，註冊參展單位包括有污染防治廠商、儀器廠商、政府機構、顧問公司及學術機構等計有 168 個單位，相關名單如表三所示。本署展示攤位在本次展覽期間，計吸引 200 多人次造訪，並有 52 位人士對環保科技園區感到興趣且留下名片。



圖十三　展覽場地實況

表五　A&WMA Annual Conference and Exhibition 展覽廠商名單

Adwest Technologies Inc.	AMEC Earth & Environmental	Bio Reaction Industries
AeroMet	Apex Instruments, Inc.	BNA
Air Compliance Testing	ARCADIS	Calgon Carbon Corporation
Air/Compliance Consultants, Inc.	Ashtead Technology Rentals	California Analytical Instruments, Inc
Air Quality Analytical, Inc.	Atmospheric Systems Corp.	Campbell Scientific, Inc
Air Quality Services, LLC	Bacharach Inc.	Centek Laboratories, LLC
Air Sampling Associates, Inc.	Barr Engineering Company	CH2M HILL
Air Toxics, Ltd.	Baseline-Mocon	Cherokee Instruments
Airgas	Bee-Line Software/Bowman Environ	Chromatotec
Airmetrics	Beltran Technologies, Inc.	Chrylser Dodge of White Oak
Altech Technology Systems Inc.	BGI	Citation Publishing, Inc.
Civil & Environmental Consultants, Inc	Earth Tech, Inc.	Enthalpy Analytical, Inc.
Clean Air Engineering	EarthWhys Solutions, LLC	Enviance, Inc.
Climatronics Corporation	Eco Physics, Inc.	Environics, Inc.
Compliance Assurance Associates	Ecotech	EnvironMax, Inc.
Conestoga-Rovers & Associates, Inc.	EKTO Manufacturing Corporation	Environmental Chemistry Services
CPP, Inc	EM-Assist, Inc.	Environmental Data Resources, Inc
DEKORON/UNITHERM	EMC	**Environmental Protection Administration, Taiwan**
Des Champs Technologies	EMRC	Environmental Quality Management
Desert Research Institute	Enablon	Environmental Resources Management
Dexsil Corporation	ENSR International	Environmental Supply Co., Inc.
DURR Environmental, Inc.	Entech Instruments	Environmental Technologies Program - WVHTC Foundation
Envitech-DR DAS	Giangarlo Scientific, Inc.	ICMA & The National Brownfields Conference

表五　A&WMA Annual Conference and Exhibition 展覽廠商名單（續 1）

ESS	GLOBE 2008	Indigo Technologies
FLIR Systems	Golder Associates Corporation	J.U.M. Engineering
GAI Consultants, Inc.	Government of Canada - Environment Canada	KIN-TEK Laboratories Inc.
GE Energy	Grimm Technologies	Kuttner North America
Geo-Con, Inc.	Heritage Environmental Services	L&E America/Tann Corp.
Geotech Computer Systems, Inc.	hydroGEOPHYSICS, Inc	Lakes Environmental Software, Inc.
Lancaster Laboratories Inc.	McGill Air Clean Corporation	Millennium Instruments, Inc.
LAND, an AMETEK Company	Met One Instruments, Inc.	N.A.Water Systems
Leak Surveys	Metco Environmental, Inc.	NASA
Locus Technologies	Michael Baker Jr., Inc.	New Age/Landmark
MacDonald, Illig, Jones & Britton LLP	Microbac Laboratories Inc	Nexus Solutions Inc.
Maxxam Analytics Inc.	MikroPul	Northrop Grumman Mission Systems
Ocean Optics, Inc.	Photovac	QMI - Quality Managment Institute
Ogawa & Co., USA, Inc.	Yes-Sun Environmental Biotech Co., Ltd	R.M. Young Company
OPSIS Inc.	Pollution Engineering	RTP Environmental Associates, Inc.
Pace Analytical Services, Inc.	Pollution Equipment News/Rimbach Publishing Inc.	Sabio Instruments, Inc.
PCE Monarch	Praxair Specialty Gases & Equipment	Scott Specialty Gases, Inc.
Perillon Software, Inc	Process Combustion Corporation	Severn Trent Laboratories, Inc.
Perma Pure	Spectrum Systems, Inc.	TIGG Corporation
SICK MAIHAK, Inc.	Sponge-Jet	Tisch Environmental Inc.
Siemens Water Technologies	TechniData America	TRC Environmental Corporation
Sigma Adlrich/Supelco	Teledyne Monitor Labs, Inc.	Trinity Consultants
SIR, SA	Telops Inc	Turbosonic
SKC Inc.	Testo, Inc.	Turner Envirologic
Spectra Gases, Inc.	Thermo Fisher Scientific	TVA Resource Management

表五　A&WMA Annual Conference and Exhibition 展覽廠商名單（續 2）

University of Denver	US EPA - ETV	US EPA - NCER
URG Corp	US EPA National Environmental Performance Track	US EPA - NERL
URS Corporation	US EPA - NCEA	US EPA - NHEERL
US EPA - NRMRL	VICI Metronics, Inc.	Weston Solutions, Inc.
US EPA - OAQPS	Vista Analytical Laboratory	William S. Hein & Co.
US EPA - Brownfields Cleanup and Redevelopment	VOC Technologies	Wheelabrator Air Pollution Control, Inc.
Wasson-ECE Instrumentation	The Weavertown Group	Wolters Kluwer Law & Business
Spectrum Environmental Sciences, Inc	Thomson West	Universal Analyzers, Inc.

展覽期間國際人士前來觀摩詢問，本署除積極向參觀人士介紹我國環保科技園區之規劃理念外，亦以宣導手冊介紹園區之硬體設施係以生態型基礎設施規劃，包括量產實證區、研究發展區、支援設施區、管理中心及教育展示區等四區，園區的運作系統、建築物及營運設施等，係採用生態工法進行園區土木建築、景觀及環境綠化等基礎設施，以營造生態化的基礎建設環境，並搭配周邊產業作適度規劃，俾使企業營運更具群聚效應，而獲得更佳的發展條件與商機。另外，我國許多學者專家前來參加此次研討會及展覽會，在得知本署在此盛會中展示推銷「環保科技園區」之招商理念，紛紛表示支持，亦鼓勵我國政府部門應多多爭取參與相關國際性研討會或展覽會，增進國際社會對台灣之瞭解，爭取在世界舞台之能見度及開拓商機，圖十四爲本署展覽攤位照片。

圖十四　本署展覽攤位相關剪影

三、卡內基美隆大學（Carnegie Mellon University）參訪紀要

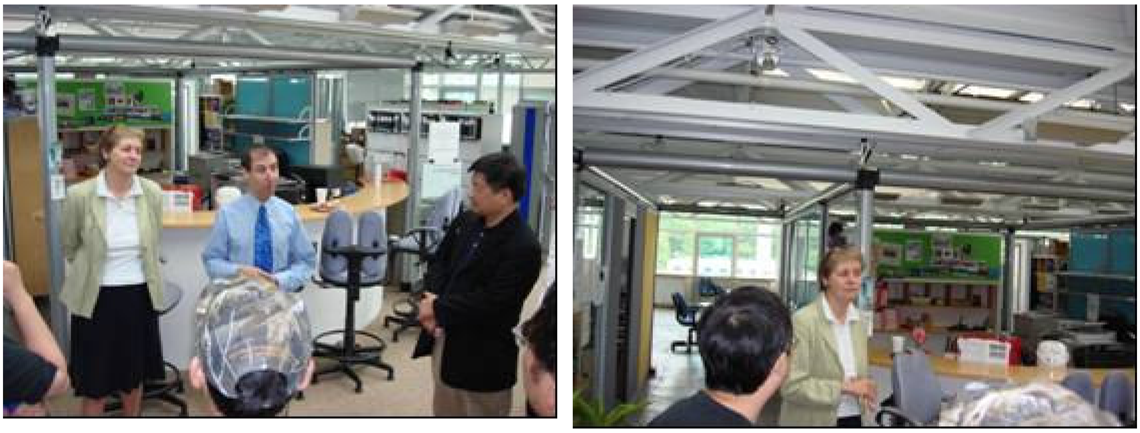
在結束研討會及參展行程，本署透過工業技術研究院及台灣專家學者協助，相關人員於 6 月 29 日上午 10 時，由本署管考處楊慶熙處長帶領工作人員及台灣多位學者，前往卡內基美隆大學土木與環境工程系所拜會 Cliff I. Davidson 教授，據 Davidson 教授表示曾經指導過兩位台灣留學生，因此，對台灣甚為瞭解。為迎接參訪團成員到訪，Davidson 教授首先在會議室接見大家，並安排其博士班研究生 Harris 向參訪團成員說明其研究主題及發現，如圖十五所示。

圖十五　Cliff I. Davidson 教授接見參訪成員

隨後 Davidson 教授引領大夥參觀其位於 Hamerschlag Hall 上之 green roof，此綠色屋頂是其"Sustainable Engineering"課程的上課地點，如圖十六所示；接著，Davidson 教授帶領大家參觀校園、建築工程系之綠建築及其空污實驗室等地點如圖十七至圖十九所示。

圖十六　Cliff I. Davidson 教授介紹其"Sustainable Engineering"課程的上課地點_green roof

圖十七　Cliff I. Davidson 教授介紹 Carnegie Mellon University 校園及參訪人員於校園合影



圖十八　Cliff I. Davidson & Vivian Loftness, FAIA 教授介紹該校綠建築_Intelligent Workplace

圖十九　Cliff I. Davidson 教授介紹其空污實驗室

針對卡內基美隆大學的綠建築，Cliff I. Davidson & Vivian Loftness, FAIA 兩位教授特別介紹，他們稱為 Robert L. Preger Intelligent Workplace，該建築物被用來實地展示下一世紀之商業建築模型，可以用來提昇環境資源的永續利用，且能維持高品質的室內環境。該綠建築包含下列幾點特色：

a. 最大化的自然調節及提供大化的個別空間進入自然環境（Maximize Natural Conditioning & Maximize Individual Access to the Natural Environment），如自然通風與日照。
b. 最佳的工程設計減少材料的使用（Optimize Design/Engineering to Reduce Material Use），如使用回收材料、低廢棄物的製造程序。
c. 零廢棄的快速建造程序（Maximize Speed of Constructability, No-waste Construction Processes）
d. 建築材料完整性及永續使用（Maximize Integrity and Material Sustainability），如套件或模組組裝。

圖二十所示為該綠建築興建照片，說明該建築物係使用模組元件，相關材料均以最少的包裝，僅有4天施工建造過程，且其使用模組式的隔間，相關工件結合處採用螺絲連接，使用的鋼材為100%回收再利用材料。

Modular components

Minimum packaging

4 day erection process

Modular structural bays

Bolted connections

Internalized structure - Stressed-skin roof and facades without penetration

Nucor-Yamato 100% recycled steel; Prefabricated modular trusses & columns

圖二十　Robert L. Preger Intelligent Workplace 綠建築興建照片（摘自 http://www.arc.cmu.edu/cbpd/iw/index.html）

參、心得

一、 研討會論文發表—應鼓勵研究、發表與參與

本次研討會中本署計有三篇論文發表，一為「零廢棄政策」，二為「廢棄物 E 化與 M 化管理」，三為「運用 OP-FTIR/AERMOD 評估製藥廠臭味負荷之研究」，楊慶熙處長在世界性的空氣及廢棄物管理協會〔A&WMA〕100 週年研討會上發表我國之「零廢棄政策」及「事業廢棄物電子化及行動化之管制」，說明我國現階段對於廢棄物管理之策略與現況，使與會代表對我國成功之執行案例留下深刻印象，對我國在廢棄物管制之努力做一廣泛性、全球性的宣導。而張文興研究員發表之「運用 OP－FTIR/AERMOD 評估製藥廠臭味負荷之研究」論文，以運用遙測技術搭配污染擴散模式調查臭味污染事件，亦引起與會代表之極大興趣，宣揚我國研究技術之先進，在此研討會中除讓與會人士對台灣各項環境保護管理議題之用心多一層瞭解，也進一步提昇台灣在國際間之能見度。本次研討會中台灣計有 61 篇論文發表，顯見對環保議題、技術等之研究成果相當豐碩，政府或民間業者應計畫性持續獎勵研究及參與國際相關專業研討會，以維持研究經費來源及提昇研究品質。

二、 環保科技園區招商--政府與民間業者均應積極準備與調整營運方針，以積極引進環保高科技及綠色生產

針對我國推出之環保科技園區，係以「產業共生、資源共享、資訊互通、風險分攤」為規劃藍圖，開創「高級資源再生技術」、「高級環保技術」及「生態化產業」等三大產業發展主軸，所以積極尋求世界各地之高級環保科技共同合作，整合國內外環保產業技術，是當前最重要課題，而配合國家整體發展趨勢，環保科技園區目前規劃引進產業，可以區分為六大產業：

(一) 與清潔生產技術相關連之產業：提供工業製程、產品及服務，進行清潔生產之改善。

(二) 回收再生資源以創造生態化之產業：以回收廢棄物或製程中副產品，轉製爲基本原料之產業。

(三) 應用再生資源以轉換成再生產品之產業：回收廢棄物或製程中副產品，轉製爲其他功能或用途之產品。

(四) 開創具新興與策略性之環保技術產業：引進高級化學、生物、物理等環保技術，培育環保人才，建構綠色產業科技。

(五) 再生能源產品與系統製造產業：再生能源利用與廢棄物能源回收，改善能源結構，促進永續能源利用之科技產業。

(六) 關鍵性環境保護相關產業：環保技術、環保關鍵性組件或設施之製造與開發。

另對於空氣品質改善技術、廢污水循環再生技術、土壤復育技術、再生能源、廢棄物分類與資源化等，亦是配合環保政策推動所要求之技術範圍。因此，在鼓勵企業設廠投資、專利技術轉移或與國內企業資金合作投資，除政府積極推廣招商提供相當優惠措施外，台灣民間產業界亦應積極配合，調整企業經營方針，以有效結合國內外專業人材、最新技術及資金，取得市場先機，方能永續發展。

三、 卡內基美隆大學的綠建築—強調資源回收再利用與自然調節

該校建築物被用來實地展示下一世紀之商業建築模型，在建築物設計包含有最大化的自然調節功能，如自然通風與日照減少冷暖氣之使用，達到節能效用，最佳的工程設計減少材料的使用，如使用回收材料及低廢棄物的製造程序，零廢棄的快速建造程序，保持建築材料完整性，可重複使用，以達到永續利用目標，如套件或模組組裝材料，達到落實省能及資源循環再利用之目標。

肆、建議事項

爲因應國際環保潮流與趨勢，我國目前積極設置「環保科技園區」，推動綠色產業發展，以建立循環型社會並開創全球化環保市場，不僅廠商應致力於研發符合國際環保標準之產品、技術，國內資源回收相關政策與法規亦應配合國際趨勢不斷的調整，積極主動與國際接軌。經本次赴美國參加 A&WMA 研討會暨國際環保工業技術展覽會，並參閱相關資訊提供建議如下：

一、鼓勵研究發表論文，爭取參與國際事務

對於每年之 A&WMA 研討會暨國際環保工業技術展覽會，應經常鼓勵研究及投稿發表研究成果，並派員參與會議觀摩學習，促進交流，以提昇台灣能見度及形象，同時對於國際實務發展之趨勢，亦能有效掌握。此外，政府應鼓勵國內學術界爭取舉辦類似會議，不僅可以增加台灣在國際間之形象，更可以提供國內廠商與國際知名廠商互相瞭解及合作機會，同時也可增進我國的觀光事業發展。

二、積極推動「全分類、零廢棄」政策，做爲「環保科技園區」推動基礎

「環保科技園區」之六大產業，需要政府強力推動，始能產生市場機制，因此，積極推動「全分類、零廢棄」政策，推廣綠色環保標章產品，並藉由 e 化管理，減少廢棄物產出，強化廢棄物管理機制，可做爲推動廢棄物回收產業之基礎，提昇廢棄物回收技術有效降低廢棄物的產生，增加回收收益並減少資源浪費，進而促使「環保科技園區」形成衛星鍊結體系的資源再利用循環，建構環境與經濟不悖的新經濟體系，形塑循環型生態社會。

三、提供獎勵措施引進國外高科技帶動綠色產業

藉由獎勵措施引進國外先進技術與本國設備生產廠商的結合，在環保科技園區建立營運基地，以解決國內迫切的環保與資源不足之問題，並可以進一步藉地利及人文之

便，向亞洲地區包括中國及東南亞等市場進軍，建構起高效益的綠色產業營運模式，並以「投資台灣、亞洲佈局」，做爲推動環保科技園區的一個重要指標。

四、強化環境教育建立生態循環型社會共識

我國目前已在桃園縣、台南縣、高雄縣、花蓮縣等地設置環保科技園區，啓動綠色產業發展、建立循環型社會與開創全球化環保市場，除了促進廢棄物之資源轉換再生利用外，將可帶動民間投資設廠，活絡經濟發展、創造就業機會，因此藉由不定期舉辦演講、教學及各種宣導活動以強化環境教育，建立生態循環型社會之全民共識，進而積極投入推動。

全文完

附錄

壹、環保科技園區英文宣導手冊

貳、 發表論文資料

Zero Waste Policy for Municipal Solid Waste in Taiwan

Soon-Ching Ho, Shou-Chien Lee, and Ying-Ying Lai
Environmental Protection Administration, Executive Yuan, Taiwan
41, Section 1, Chung-Hwa Rd.,
Taipei 10042, Taiwan

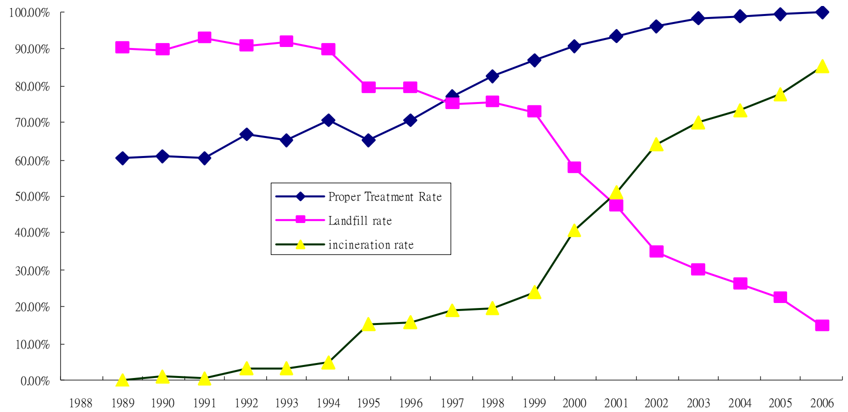
INTRODUCTION

The construction and operation of large Municipal Solid Waste (MSW) incineration plants and sanitary landfills in Taiwan has significantly alleviated the dumping problems of MSW in Taiwan. With rising demands for better environmental quality, acquiring lands for MSW incinerators and landfills has become more difficult for the government. Environmental groups and legislators also expressed great concerns over the impacts of MSW treatment facilities and asked the government to adopt more progressive waste prevention policies. Embracing some developed countries' "zero waste" visions, Taiwan Environmental Protection Administration (TEPA) initiated a "zero waste" policy for MSW in 2003, marking a milestone towards sustainable use of the resources of the society.

REVIEW OF TAIWAN'S MSW MANAGEMENT

There was no proper treatment of MSW before 1984 in Taiwan. Most of the MSW was dumped or disposed of in unqualified facilities, without adequate environmental and sanitary concerns. To solve the problems, Taiwan began the construction of sanitary landfills in 1984 for proper waste treatment, and the construction of incinerators in 1991, with consideration of higher requirements for environmental quality, the difficulty of land acquisition for landfills, and the maturity of MSW incineration technology. As of 2006, there are 22 MSW incinerators in operation, turning garbage into electricity, with a total treatment capacity of 18,000 metric tons per day. Thus the MSW treatment approach has been gradually shifted from landfill to incineration; the weight of MSW incinerated reached 85.2% in 2006 (Fig. 1), and the proper treatment rate promoted to 99.8%, which was incomparable to the 2.4% in 1984.

Figure 1 MSW treatment approach before year 200



As for MSW recycling, Taiwan started implementing Extended Producer's Responsibility

(EPR) programs for consumer products in 1988 in accordance with the Waste Disposal Act (WDA) Amendments of 1988. In 1997, TEPA initiated the so-called “Four-in-One Resource Recycling Program”, which coordinated the efforts of the public, recycling businesses, municipalities, and the recycling fund for a comprehensive recycling of items listed under the EPR programs. The recycling fund is collected by TEPA from the enterprises obliged by WDA to take back and to recycle their post-consumer products under the EPR programs. Table 1 shows the product items subject to the EPR programs as well as their recycling rates. As a result, the resource recycling rate of MSW has reached 34.97% by end-2006 (Fig. 2), and the waste collected and shipped to incinerators or landfills per capita per day has dropped from the peak 1.14 kg in 1997 to 0.61 kg in 2006 (Fig.3).

Table 1 The Recycling Rates of Products Subject to EPR (Jan. - Oct. 2006)

Item	Recycling Rate
General Containers	78.98%
Pesticide and special environmental agents containers	94.77%
Dry batteries	59.67%
Motor vehicles	41.20%
Lead-acid batteries	78.70%
Tires	63.85%
Lubricants	4.08%
TV, refrigerator, washing machine, air conditioner	48.61%
Computers (PC, monitor, notebook, printer)	45.44%
Longitudinal fluorescent light tubes	61.82%
Fans, incandescent light bulbs and other fluorescent light tubes	To be enforced from July 2007

Figure 2 Resource recycling amounts and rates of MSW from 2000 to 2006

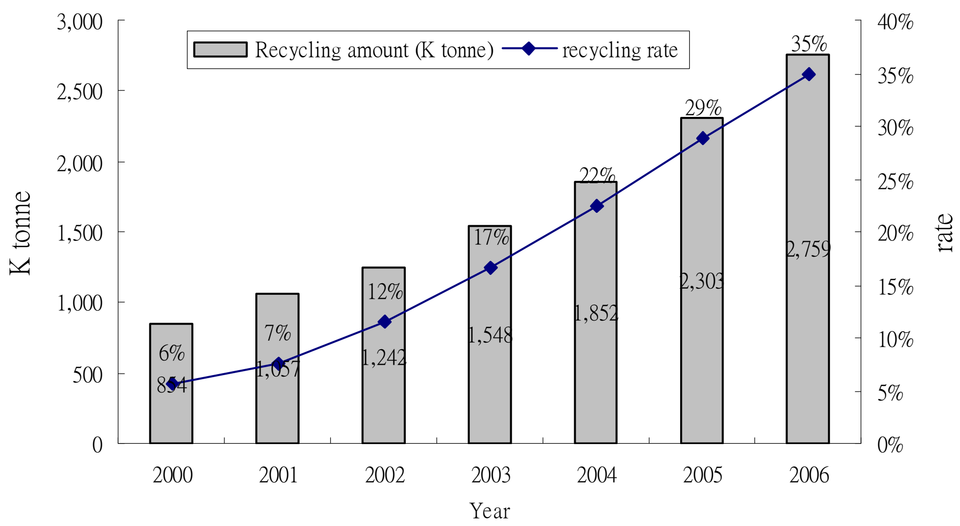
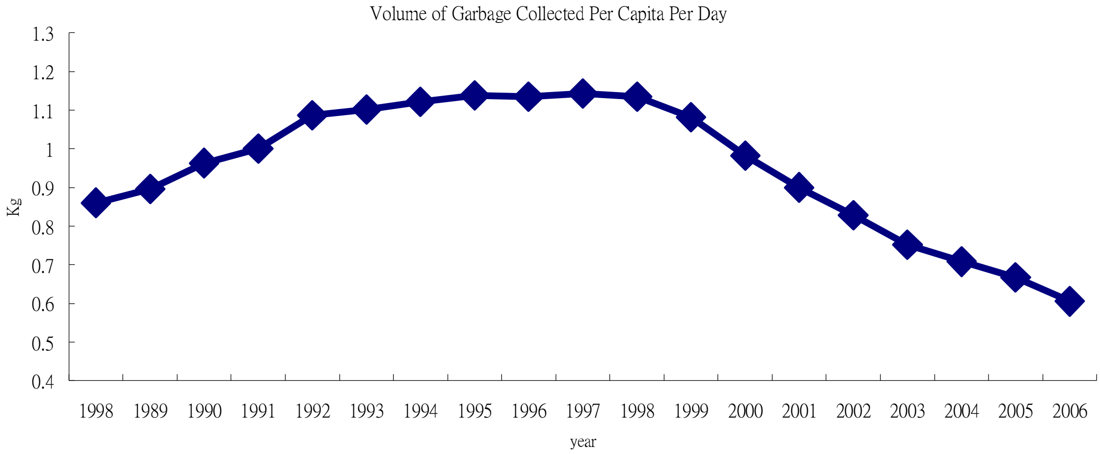


Figure 3 MSW collected per capita per day



ZERO WASTE POLICY

To meet the goals of sustainable society and to respond to growing concerns over the environmental impacts of MSW incinerators and landfills, TEPA initiated a "Zero Waste Policy" for MSW in 2003. The policy reflects the shifting philosophy of waste management from end-of-pipe treatment to source reduction and resource reutilization. The zero waste objectives are based on the volumes of MSW collected in 2001. The goals of volume reduction are set for 25%, 40% and 75% by the end of 2007, 2011 and 2020. Besides, combustible MSW is not allowed to be disposed of in landfills except for remote areas after 2007. The policy lays out four major strategies: source reduction, reuse, recycling and green consumption.

■ Source Reduction

Source reduction aims to minimize the toxicity and generation of wastes. TEPA has enforced two packaging restrictions since 2002. The "Restriction on the Use of Plastic Shopping Bags and Disposable Tableware" rule, implemented in two stages from July 2002, prohibited the regulated stores from providing disposable plastic tableware and plastic shopping bags thinner than 0.06mm. For plastic shopping bags thicker than 0.06mm, the regulated stores are not allowed to offer them for free. From September 2006, all disposable tableware is banned in government agencies and schools. The "Restriction of Excessive Packaging" rule, also implemented in two stages from July 2006, limits the packaging volume and the number of packaging layers of computer program optical disks and gift boxes containing pastries, processed foods, cosmetics, and alcoholic beverages. TEPA estimated that the two packaging restriction rules together can annually reduce the volume of wastes by 14,000 metric tons. More disposable products are targeted in the next phase of waste reduction measures.

In light of the fact that non-rechargeable alkaline manganese batteries and manganese-zinc batteries are used and disposed of in large quantities, TEPA has prohibited the manufacturing, import, and sale of such batteries containing more than 5 ppm of mercury, complementing the existing battery recycling program. TEPA is also considering a rule to restrict the use of mercury-containing thermometers and manometers to cut down mercury in waste streams.

Eco-design of products is an important measure for source reduction. In accordance with article 12 of the Resource Recycling Act (RRA) and European Union's Directive on

End-of-Life Vehicles, 8 domestic vehicle manufacturers, with support from the Ministry of Economic Affairs and the Taiwan Transportation Vehicle Manufacturers Association, signed into an agreement to voluntarily practice greener design of new vehicles in October 2005. The agreement specifies the following requirements for new cars entering the Taiwanese market from 2008:

1. Recyclability and recoverability shall be more than 80% and 85%.
2. Restrict the use of mercury, cadmium, lead and chromium VI.
3. Plastic components over 100g and rubber components over 200g must be labeled in accordance with international standards.
4. Manufacturers shall provide information for car dismantling.

As eco-design has become more popular with industry and the government to reduce the environmental impacts of products, it is expected that more source reduction measures will be initiated and implemented by TEPA and other agencies in the future.

■ Reuse

TEPA started to promote the reuse of retired furniture in 2003. By the end of 2006, 19 furniture recycling plants had been established nationwide to repair, refurbish or dismantle abandoned furniture or bicycles. From 2003 to 2006, 58,000 pieces of renewed furniture and bicycles were sold, creating revenues up to NT$ 3.4 million (33 NT$ =1U$ on March 12, 2007). TEPA will include small appliances in the reuse program, with a goal to renew 18,500 pieces of furniture, bicycles and appliances. In 2020, an estimate of 70,000 metric tons of furniture, bicycles and appliances will be reused or recycled, generating a benefit of NT$ 250 million.

■ Recycling

Adding to the EPR program that mandates the producers to shoulder the responsibilities of taking back and recycling post-consumer products, two initiatives implemented by Taipei City government and TEPA, respectively, aim to lure or mandate the general public to separate waste for recycling. Since 2000, Taipei City government has initiated the implementation of a "Per-Bag Trash Collection Fee," based on the principle of "Pay As You Throw." Citizens must pay for and use special trash bags for trash to be collected by the City government. The current fee rate is NT$ 0.45 per liter. To encourage recycling, the City picks up sorted recyclables free-of-charge. The "Per-Bag Trash Collection Fee" program has successfully cut down the waste volume by 23% and boosted the recycling volume by 22%.

TEPA has implemented a mandatory garbage separation program nationwide since 2006. The public are required to sort garbage into three categories before pick-up, namely the recyclables, kitchen wastes and trash. Warnings will be issued for the first non-compliance. A penalty of NT$1,200 will be imposed on the second violation. Kitchen wastes are either sanitized and recycled for livestock feeding or composted. Compared to 2005, volumes of MSW collected in 2006 dropped by 14.2%, and the amounts of recyclables collected increased by 51.4%. Kitchen wastes collected have jumped to 569,862 metric tons, a sharp increase of 90%.

House refurnishing wastes have not been properly sorted and recycled in Taiwan. TEPA has initiated a program to offer individual house owners collection services of such wastes for further sorting and recycling starting 2008.

The MSW incinerators generated 860,000 metric tons of bottom ash and 150,000 metric tons of fly ash in 2005. Only 30% of the bottom ash was recycled in one recycling plant as aggregates. TEPA has provided grants for 10 local governments to implement bottom ash recycling plans. Two new bottom ash recycling plants are under construction.

To encourage the development of environmental and recycling technologies, TEPA has been planning and constructing four Environmental Science and Technology Parks (ESTP) in Taiwan. The ESTP focuses on three major categories of industries: advanced resource recovery technology, advanced environmental technology, and eco-industry. Cooperative partnerships with world-class environmental companies are being sought in this endeavor, with an aim of developing a low-pollution and high value-added eco-business model, while balancing production, living and ecological aspects of the society. Companies qualified to an ESTP will receive special subsidies ranging from real estate leasing or purchase, production and research from TEPA. The ESTP project aims to accelerate the circular and sustainable use of substances to reach the goal of recycling and renewing three million metric tons of wasted material as resources annually.

■ Green consumption

To increase demands for "greener products," TEPA has implemented the "Government Green Procurement" program since 2002. The program sets a minimum procurement quota for government agencies to buy products certified as "eco-products" by TEPA or the Ministry of Economic Affairs. By end-2006, 3,524 products were certified as "eco-products." In 2005, Taiwanese governments as a whole bought NT$6.8 billion worth of "eco-products". In addition to public procurement, TEPA has been actively promoting private companies to green their purchases of consumer products. The sale of eco-products is expected to rise to NT$ 7.5 billion in 2007.

SUMMARY

Building on adequate infrastructure for MSW treatment, Taiwan's MSW management policy has shifted focus from end-of-pipe treatment to waste prevention. TEPA has initiated a "zero waste" plan for MSW, which sets a long-term goal of 75% reduction of MSW by the end of 2020 based on the MSW volume in 2001. Major strategies to achieve the goal include source reduction, reuse, recycling and green consumption. By implementing programs in accordance with the strategies, Taiwan will take a step forward towards a sustainable society.

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The e-Revolution and Mobilization of Waste Management in Taiwan

Extended Abstract #333

Ching-Shi Yang and Soon-Ching Ho
Environmental Protection Administration, Executive Yuan, 41, Section 1, Chung-Hwa Rd.,Taipei 10042, Taiwan

ABSTRACT

Taiwan established the "Industrial Waste Control Report System" in 2000 to prevent illegal dumping of waste. This online reporting system is aimed at waste flow tracking (auditing) and investigation of violations. It is part of an effort to control the waste flow from **cradle to grave**. Different from other systems run by other countries, it requires the waste generators and transporters, as well as the treatment, storage, and disposal facilities (TSDFs) to report online the movement of industrial waste within 24 hours after it has been shipped, received or completely treated. The designated generators also need to report the monthly rate of waste generation. The reported data is checked on a daily basis. On-site investigation is conducted if any violation is suspected. This system also provides On-Line Analytical Processing (OLAP) for reporters to analyze all their data, so as to encourage self-management of waste. Currently there are 18,126 generators, 3,766 transporters, and 833 TSDFs that are required to make online reports. The reported amount of waste is about 15 million tonnes per year, which is about 80% of the waste generated in Taiwan. About 20,000 people visit the website daily either to report the waste flow or view the web information. It serves as a "single portal" for industrial waste management. This system also succeeded in monitoring the disposal of medical wastes from Severe Acute Respiratory Syndrome (SARS) patients to ensure the wastes were properly treated in 2003. Starting in 2002, 1,600 vehicles that transport hazardous waste were required to install a Global Positioning System (GPS) and transmit their position data every 30 seconds to the same website. Along with the manifests being reported online, the routes can be traced and verified. Illegal dumping cases have been reduced tremendously since then. Another 4,000 GPSs will be installed on the remaining shipping vehicles within the next three years.

INTRODUCTION

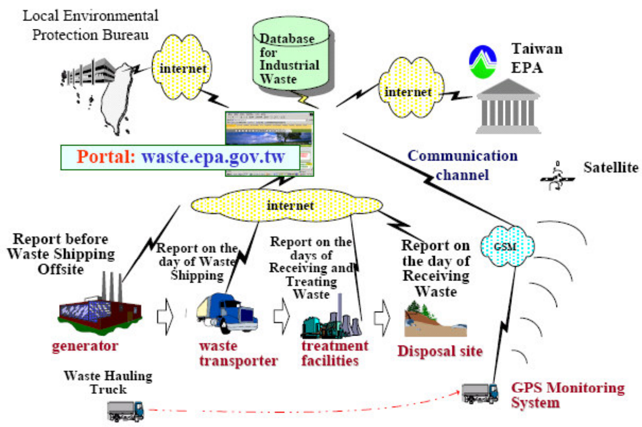
This article explains waste management tools employed by the government of Taiwan. One of these tools is the use of online reporting by parties involved in waste activities to establish a comprehensive waste activity tracing system. This system serves as a single portal form of public service, known as the Industrial Waste Control Center Report System (http://waste.epa.gov.tw)[1].

Currently there are 90,000 factories, nearly 20,000 medical institutions, and at least 20,000 new demolition sites acting as waste generators. They generate 26 million metric tons each year, a huge burden for an island with an area of 36,000 square meters. There are 170 illegal dumping sites classified as severely polluted. A significant amount of money is spent on soil and groundwater remediation. These sites came into being as a result of economic development and management difficulties. Paper manifests were used in waste tracking in the past; this method was time-consuming and very inefficient to monitor the waste flow. The governmental role in waste management in Taiwan involved at least five ministries.[2] The communication between these ministries (such as the Environmental Protection Administration - Taiwan EPA), the central industry authorities, and local enforcement authorities was inefficient and costly. The Taiwan EPA initiated the online system in 1998 to better manage tracking. After three years of testing, the Industrial Waste Control Center was officially established in 2000. It offers functions like online integration, mobilization, and OLAP analysis. The reporting system has been improved to not only trace the waste flow, but also to monitor the actual amount of waste generated.

METHODS

The goal of the Industrial Waste Control Center is to establish a management system for waste disposal from cradle to grave. This management system includes baseline information management, waste disposal and treatment facility permit management, and waste flow activities management. This is now done completely in electronic form and online. The Center relies on the Industrial Waste Control Report System, which designated 40,000 generators to manage baseline information, such as their production capacity and raw material input, and requires 20,000 of these designated generators who generate large quantities of industrial and hazardous waste to report waste generation and flow online.[3]

Waste disposal facilities must report the arrival of waste after they have received it in order to double check the amount. GPSs are installed on disposal vehicles to transmit their locations back to the Center. In that way, the inspectors are able to trace the disposal route and waste flow, as well as verify the information with the manifests reported.



Satellite

Figure 1. Flow chart of waste disposal tracking and management.

The waste disposal tracking and management system is shown in Figure 1. It is the first system that employs online reporting by various parties associated with waste flow activities to trace the flow of waste and its disposal. Due to the satisfactory performance of the tracking system, the scope has been gradually enlarged by designating more waste generators or waste disposal facilities.[4] The growing trend of designated generators is shown in Figure 2. There are around 20,000 generators who make online reports, representing 22% of the total generation sources. Their reported waste quantity makes up 80% of the total quantity of waste generated nationwide. The other 20% of waste generation is from disposal facilities that make monthly reports on waste generation without manifest reporting.[4] This system ensures total control over industrial and medical waste disposal.

Figure 2. The growing trend of designated businesses.

The system is designed for reporting the designed waste activities, e-government service, and regularly auditing and carrying out daily QA/QC to ensure the data gathered is correct. Most applications and permit issuance are handled online. The report data is audited to find out about illegal activities such as waste disposal exceeding permitted quantity, or waste materials not corresponding to categories of waste permitted by the government. There are around several hundred cases investigated each year. Indeed, this system achieves the goal of promoting environmental protection. Figure 3 explains the control management and application items. The system framework is explained in the sections below.

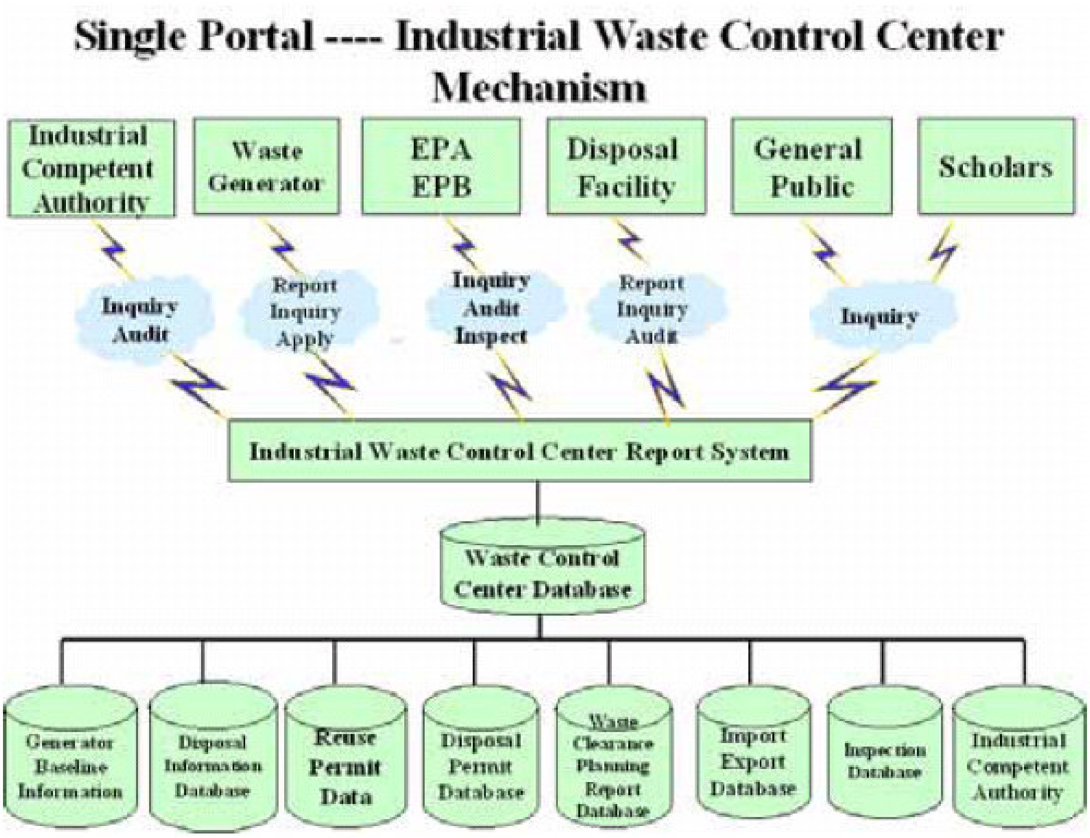


Figure 3. Diagram of waste management single portal.

Generator Management

This system requires designated generators to report online waste generation categories and quantities, raw materials used, and products produced in order to establish waste generation baseline information. It also uses an online auditing system to manage baseline information from around 40,000 generators. Since 2002, there have been about 20,000 generators designated as major targets.[5] They must report production capacity, raw material usage,[6] or generation quantity monthly in order to update their baseline information. These businesses are also required to report temporary waste storage quantities, and the mass balance concept is used to instantaneously calculate all the disposal quantities reported. Waste properties and reported waste quantities are compared together with generators using the same production process to ensure the reported amounts are correct. To reinforce the self-management of each business, this system offers rapid self-auditing functions for waste generation, statistical analysis to balance temporary storage quantity and disposal quantity, reported data as compared with permitted quantity, disposal quantity trend changes over the years, and GPS tracking inquiries. Businesses do not need to construct their own systems. Using this system will assist businesses in following regulations and raising self-management efficiency and competitiveness. Businesses are able to participate in government policy and have more confidence in the government.

Waste Flow Tracking Management

According to the Taiwan EPA regulations, waste disposal facilities must report waste reception information and waste reception quantities online as waste arrives at their facilities. Waste generation quantities and condition after treatment or reuse must be reported online as well. This ensures all waste generated is properly treated. An important aspect of waste management is to establish correct disposal or treatment information. The system audits waste manifests against disposal, treatment, and recycling permits to determine violations in terms of disposal quantity exceeding the permitted quantity, disposal of waste categories not listed in the permit, and waste disposal vehicles simultaneously registered under two or more transporters. These cases were investigated and citations made accordingly. Since 2002, the Taiwan EPA has required industrial waste disposal vehicles have real time tracking systems installed.[8]

Vehicle specifications and maintenance were also regulated.[8] Wireless technology allowed disposal vehicles shipping hazardous waste or wastes that are easy to dump to be installed with a real time tracking system. There were 1,645 vehicles that passed the system test. In the next three years, another 4,000 disposal vehicles will be installed with the tracking system and will be monitored. The disposal route and waste generator report data will be compared against each other, and barcode scanning will replace the manual reading of manifests. The UTM axis is joined with internet auditing to easily track the route of hazardous waste liquid. If a suspicious vehicle enters an important water source protection area, the alarm system will be triggered. Inspection officers can inspect suspicious cases at anytime. This system offers a PDA inquiry function. A designated vehicle route is tracked and random inspection is conducted. A PDA is also used to report back the inspection result. To achieve the goal of controlling the trans-boundary movement of waste, beginning in 2002, the system required that exporters must report online the manifest describing the route, amount, and categories from the storage area to the port, and a corresponding English version manifest. Foreign treatment facilities must make online reports to confirm waste received. The exporter and the foreign treatment facilities have been following the regulation requiring online reporting.[4]

This is the first online management system in the world that traces waste trans-boundary movement.

On Site Inspection and Auditing

To control the accuracy of the reported data, the Taiwan EPA has mandated inspection offices or uses professionals to conduct onsite inspections of more than 10,000 cases each year. Frequent inspection of waste generation and storage is combined with comparing the reporting data with onsite inspection leading to greater than 90% reliability of the reported data.

Statistical Analysis and Strategy Support

To overcome the difficulties of prompt inquiry into 30 million records, this system uses On Line Analysis Processing (OLAP), which calculates large quantities of historical data into a multi-dimensional cube (Figure 4). The cube can have more than five categories. Data conversion into a multi-dimensional cube allows for rapid inquiry, statistical analysis, and auditing functions. Competent authorities can use this information when formulating waste management strategies.

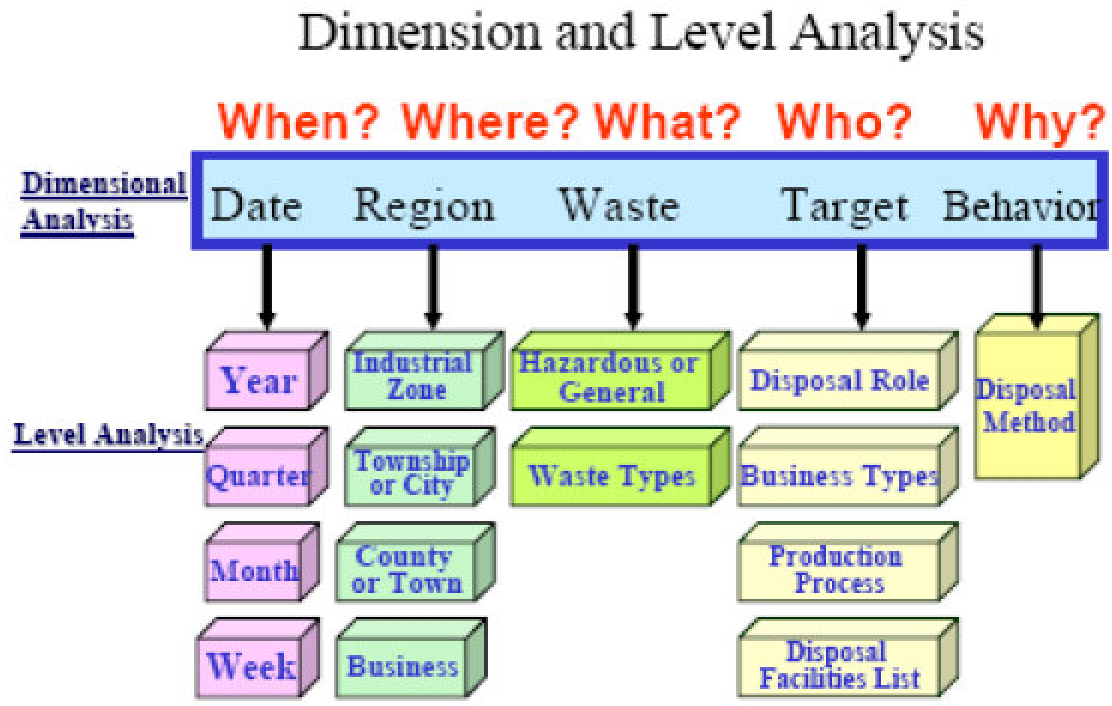


Figure 4. OLAP system dimensional analysis and application.

RESULTS

The Industrial Waste Control Report System was constructed by the Taiwan EPA and shared with each local enforcement authority and other industry competent authorities. It saves more than 30 million NT dollars (one million US dollars) in administrative costs annually. After this system was established, there were only a few cases of illegal dumping of demolition waste in the past two years. Our environment has profoundly benefited from this system and the benefits it has brought include:

1) Barriers to communication obstacles with other industry competent authorities are removed;
2) Self-management and competitiveness of businesses are increased. Businesses are able to participate in policy making and have greater confidence in our government;
3) Policy makers utilize analytical reports, database storage, and data mining to promptly make correct policy;
4) Waste generation and treatment capacity information is offered for businesses that are interested in setting up treatment facilities.

In 2003, during the SARS epidemic, Taiwan was designated as a severely affected region. This system promptly analyzed medical waste generation and the remaining available treatment capacity on a daily basis and offered the sanitation department a valuable source of information for decision making. The environmental management staff was able to use this system to work at home, without interruption from the threat of SARS infection. This was a successful application of executing environmental management without limitation of work location and time.

DISCUSSION

Waste disposal flow tracking involves cross boundary movement. Without using modern technology, it is difficult to monitor transportation and therefore also difficult to reach the goal of "managing waste from cradle to grave." Currently, we have established a complete database, but we will have to continue to upgrade this system by adopting the latest information technology. We will employ Radio Frequency Identification (RFID) and image transferring technology to improve the efficiency and accuracy of waste disposal monitoring. Using such technology will increase reporting efficiency and offer better public service. We will then integrate all the permit and baseline information from different departments (air, water, waste, and toxic substances).

Such a system will be a good tool to reach the goals of controlled flow of materials and sustainable development of resources. This type of management system is currently not employed in many countries, and we wish to share our successful experience with others.

SUMMARY

Industrial waste management in Taiwan takes advantage of the e-revolution and wireless technology to establish a complete industrial waste tracking system and single portal, even with limited manpower. Over 40,000 waste generators are designated in this system and more than 30 million records have been gathered. Online management enables the Taiwan EPA to promptly understand waste generation and flow. This is the first and largest system to date to use Internet reporting to manage cross boundary waste movement. It is also one of the best systems that exist worldwide to manage waste online. There are around 20,000 hits on the site each day and more than three million visitors visit the web site annually. The web site has become the most visited site among Taiwan's government web sites. The central environmental authority, local enforcement authority, and central industry authority have more than 300,000 visitors who log into the management system annually. The system offers the environmental authority a sound basis for inspecting illegal activities. This system also offers businesses a chance to conduct self-management. The system achieves the dual goals of convenient service and environmental management.

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KEY WORDS

Industrial Waste Control Report System**,** OLAP, waste management, waste tracking, Taiwan

Odor Load Estimation for A Pharmaceutical Plant by OP-FTIR/ AERMOD

Paper #a530

Wen-Shing Chang and Tzi-Chin Chang
Environmental Protection Agency, 41, Sec. 1, Chung- hua RD., Taipei, Taiwan, R.O.C.

Shiao-Shing Chen and Jung-Hua Chang
Institute of Environment Engineering and Management, National Taipei University of Technology, 1, Sec. 3, Chung-hsiao E. Rd., Taipei, Taiwan, R.O.C.

ABSTRACT
In this article, a case study was conducted to correlate the odor index and possible pollutants from a pharmaceutical plant based on the odor threshold and Open Path Fourier Transform Infrared (OP-FTIR) technique, and to model the results using American Meteorological Society/Environmental Protection Agency Regulatory Dispersion Model (AERMOD), a USEPA's local-scale air quality models. The results showed, although nine different pollutants were obtained from OP-FTIR, the contribution to the detected odor was various due to their different odor thresholds. Consequently, only pollutants with odor intensity ≥1 were used to correlate with the odor index. Odor intensity of pollutants is defined as the concentration of each pollutant divided by the odor threshold. Consequently, a linear regression equation with correlation of determination (R^2) of 0.9978 was derived between the odor index and the odor intensity of pollutants. Moreover, AERMOD was used to model the odorant dispersion route to identify the influenced area. Half-life time in the AERMOD was firstly determined through the regression analysis of the odor index to derive the exponential decay equations between sampling sites, and the half-life time were obtained as 45.20-211.72 seconds with R^2 of 0.6013-0.9909. The influenced contour for odor index and each pollutant was then obtained by AERMOD and a good correlation was observed between the AERMOD predictions and the actual measured values. From the combination of OP-FTIR/AERMOD, this approach can not only quickly identify the odorant and estimate the pollution profile, but also offer recommendation to the government and the manufacturers for improving air pollutant emission.

INTRODUCTION
Fugitive odor is a major burden for ambient residential and commercial areas, resulting from industry located near-by. Most of the odors are unpleasant and there are many complaints about these fugitive odors, especially in crowded Taiwan. Odor index is the typical method to determine the odor and the current regulation is 10 odor units for residential and commercial area in Taiwan. However, these regulations can not be implemented unless the source and characteristic of odor can be recognized. Therefore, source identification quantitatively and qualitatively becomes significant for the government to regulate these fugitive odors. In this case, a pharmaceutical plant using synthesis and ferment method to produce pharmaceutical intermediates but generating many volatile organic compounds (VOCs) during the manufacturing processes was studied. These VOCs were emitted from stack or fugitive from buildings or facilities to ambient environment accompanied with odor.

A pollutant can not be smelled as odor unless it is over its odor threshold, which is the smallest concentration of odor that will produce a sensory response in a given percentage of the population. Once the odorant concentration is over its odor threshold, it will be smelled. Methods for determining odor threshold have been conducted by several researchers. [1-5]

Walker et al.[5] selected n-amyl acetate (nAA) as a test odorant and developed a methodology in which participants received multiple presentations each session for several concentrations. Yes-no responses as to whether odor was detected were analyzed using binomial statistics, with the probability that a given proportion of yes responses (or greater) would occur by chance alone being treated as the inverse of detectability.

To measure the concentration of VOCs, both Gas chromatography/mass spectroscopy (GC/MS) and Open Path Fourier Transform Infrared (OP-FTIR) are good techniques. Nagorny and Francke[6] collected odor emissions samples with a gas sampler equipped with filter tubes containing the styrene-polymer Super Q. After elution with solvents of different polarity, the extracts were analyzed by GC/MS. Proposed structures were verified by comparison of analytical data with those of synthetic reference samples. However, the downside for using GC/MS is that the pollutants can not be identified instantaneously. OP-FTIR measurement technique is a novel method for measuring air pollution and can detect the pollutants on-site and is able to measure fugitive emissions that originate from area sources, e.g., car traffic, leakage from industrial plants and refineries, and production and emission processes.[7] OP-FTIR measurements can also produce large amounts of information on the chemical environment, and the remote sensing OP-FTIR system was also able to continuously monitor gases that are toxic and work as an alert system for the real time monitoring of hazardous gases beyond normal working conditions of various kinds of areas, such as living or industrial areas. [8; 9] Measurement of leaking gases using OP-FTIR spectroscopy was carried out by acquiring Integrated Path Concentration (PIC) data. Li et al.[9; 10] applied different optical path directions of the PIC data to create the two-dimensional contour maps for chloroform and methanol. It was concluded that mapping contaminant concentrations could help understand the peak locations of industrial emissions and estimates of pollutant distribution.

AERMOD is a plume models which is able to model short term emission for industrial sources. The plume model not only simply incorporates the traditional Gaussian plume model, but also adds the feature of turbulence and diffusion phenomenon in the atmosphere. The AERMOD modeling system is composed of one main model (AERMOD) and two preprocessors—a meteorological preprocessor (AERMET) and a terrain preprocessor (AERMAP). The features of AERMOD include its ability to treat the vertical inhomogeneity of the planetary boundary layer special treatment of surface releases, a three-plume model for the convective boundary layer, irregularly-shaped area sources, limitation of vertical mixing in the stable boundary layer, and fixing the reflecting surface at the stack base. Several researches evaluated AERMOD dispersion model for predicting industrial source emission. Kumar et al.[11] evaluated the AERMOD dispersion model as a function of atmospheric stability for an urban area and found the model predictions becoming better as the averaging period increases. The 24-h predictions are better than the 3-h predictions and the 3-h predictions are better than the 1-h predictions. Stowell et al.[12] applied the AERMOD as odor footprint tool to estimate the livestock housing odor, where the odor footprints can be developed for specific scenarios for visualizing the projected odor impact on the surrounding area. Piper et al.[13] studied the sulfur hexafluoride at known rates from a simulated volume source and measured the sulfur hexafluoride at various points in the study field by sampling network of Tedlar bag and OP-FTIR spectrometer measurements. Good correlation was found between the AERMOD (R^2 = 0.78) predictions and OP-FTIR spectrometer data. The

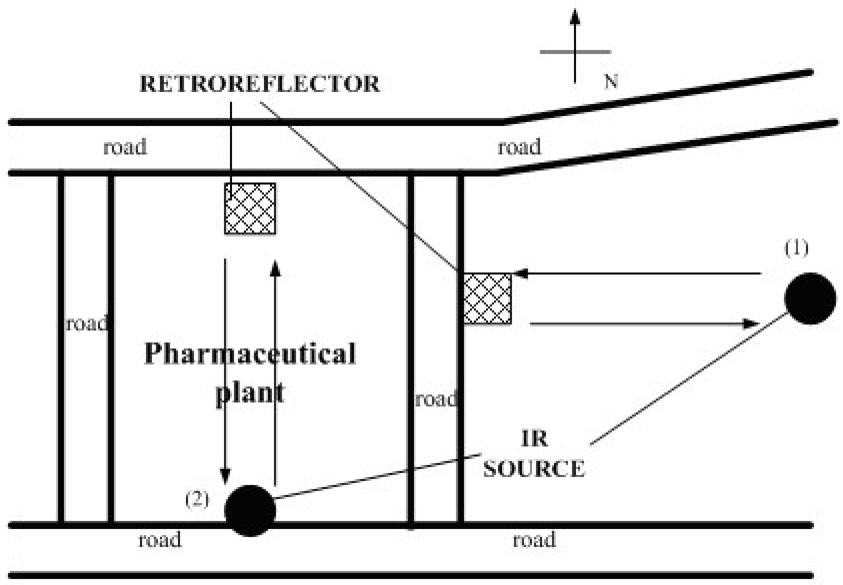
AERMOD models were found to only under-predict the OP-FTIR spectrometer data set by approximately 1.39-1.21 %.

Whereas OP-FTIR monitoring method is a noninvasive investigation procedure that could exactly and quickly identify the air emission source and the pollutants, together with AERMOD model can furthermore predict the possible influenced area. Therefore, using AERMOD as odor footprint tool to estimate the fugitive odorants dispersion route was applied in this study. Consequently, the objective of this study are to (a) monitor and identify the odorants fugitive source; (b) derive the half-life time through from the exponential odor decay equations based on the wind speeds, odor indexes and distances between sampling sites; (c) derive the correlation between odor index and odor intensity to determine the contribution of each pollutant to the detected odor; (d) apply AERMOD to estimate the odor load from this pharmaceutical plant to model the odorants dispersion route and mapping contour for the influenced area.

EXPERIMENTAL WORK

This study was performed in the industrial park located in the northern of Taiwan, and the pharmaceutical plant is the main stationary source in this industrial park. The OP-FTIR was used in this study for measuring the fugitive pollutants. Figure 1 exhibits the detecting position of the OP-FTIR spectrometer module where retroreflectors are annotated with dot and monitoring paths are illustrated with arrows. There are two IR sources and two retroreflectors, respectively. The first IR source (denoted as (1)) was positioned 350m away from the eastern side of the pharmaceutical plant according to the complaint of ambient residents. The monitoring period was between 2006/8/17 and 2006/8/25. The second IR source (denoted as (2)) was positioned on the fence of the pharmaceutical plant and both retroreflector was positioned at the other end of the IR path to monitor the emission pollutants inside and outside the pharmaceutical plant. The monitoring period was between 2006/9/29 and 2006/10/3. The meteorological data was collected by the near field meteorological station to understand the windspeed and wind direction.

Figure 1. Position of the OP-FTIR spectrometer module and retroreflector. The monitoring paths were illustrated with arrows.



The official test method of odor index in Taiwan is sampled with Tedlar bags and the samples are tested by the panel of 6 members with the sense of smell.[14] This olfactory test was managed by a person who is recognized to have proper smell function and to be the expert of the odor index measurement. Sample is prepared in one of three odor bags filled with non smell air and sealed with silicon rubber by introducing sampling gas with injector and diluted to the dilution ratio for the first test. Prepared odor bag and two odor bag with non-smell air are given to the panel. Panel selects on odor bag that he/she suspects that odor substance is injected. The selecting operation is repeated three times by each panel.

The environment sample odor index is calculated by following equation;

$$Y = A_1 \times 10^{(\frac{M-7}{M-N})(\log A_2 - A_1)} \qquad (1)$$

Where Y is odor index, A_1 is the first dilution ratio of the correct answer point of survey more than 7 of 12 times, A_2 is the dilution ratio of the correct answer point of survey less than 6 of 12 times, M is the correct answer point of A_1; N is the correct answer point of A_2. This study sampled the odor gas on the downwind at the pharmaceutical plant and its neighborhood to corporate with the OP-FTIR measurements. Samples were taken once at four different times for three different sites to get 12 samples totally.

RESULTS AND DISCUSSION

OP-FTIR Monitoring Results

For the first IR source (denoted as (1) in Figure 1), OP-FTIR spectrometer got 1642 sets monitoring data (one data set per 5-min time periods) and nine different pollutants were detected. These nine pollutants were methanol, ethyl acetate, acetone, N, N-dimethyl formamide, isopropanol, 2-butanone, ammonia, chlorodifluoromethane and cyclohexane. Molecular formula, appearance, sense of smell and statistical data for each pollutant are shown in Table 1. The detected probability is defined as detected numbers for certain pollutant divided by total monitoring numbers and the threshold probability is the number greater than odor threshold divided by detected numbers. From table 1, methanol had highest detected probability but its concentration was still less than its odor threshold concentration. The threshold probabilities for three pollutants exceeding odor threshold concentration were ethyl acetate 82.46%, acetone 92.00% and ammonia 3.22%, and the rest pollutants were all less than their odor thresholds. Although the detected probabilities for ethyl acetate and acetone were only 3.47% and 4.57%, respectively, they had high ratios to exceed their odor threshold concentrations, indicating the ambient residents had higher probabilities to nose out these two pollutants. Ethyl acetate is a clear, colorless liquid with a fragrant and fruity odor, and acetone is a clear, colorless liquid with a sweet, somewhat aromatic odor. Once these fugitive odorants emitted into the air, the complex odor was a major burden for ambient residents. Figure 2 shows the variation of concentration of ethyl acetate and acetone versus monitoring time from 350m away, indicating 30-40 times more than the threshold odors were observed.

In order to identify the pollutants source, the second IR source (denoted as (2) in Figure 1) was positioned on the neighbor pharmaceutical plant. OP-FTIR spectrometer got 1073 sets monitoring data by taking one data set per 5-min time periods, and also nine different pollutants were detected in this area. These pollutants were methanol, ethyl acetate, acetone, ammonia, chlorodifluoromethane, ethanol, dichlorodifluoromethane, hexamethyldisiloxane and t-Butyl acetoacetate. The molecular formula, appearance, sense of smell and statistical data of these pollutants are shown in Table 2. In Table 2, ethyl acetate and acetone are still the two species to exceed the odor threshold inside the plant with detected probabilities of ethyl acetate 83.70% and acetone 60.00%. Compared to the data in Table 1, the results in Table 2 indicated ethyl acetate and acetone are the two critical odor species to affect the ambient residents. Figure 3 shows the variation of concentration of ethyl acetate and acetone versus monitoring time in the second monitoring period, and high ethyl acetate was observed inside the plant.

Figure 2. Variation of concentrations for both of (a) ethyl acetate and (b) acetone 350m away.

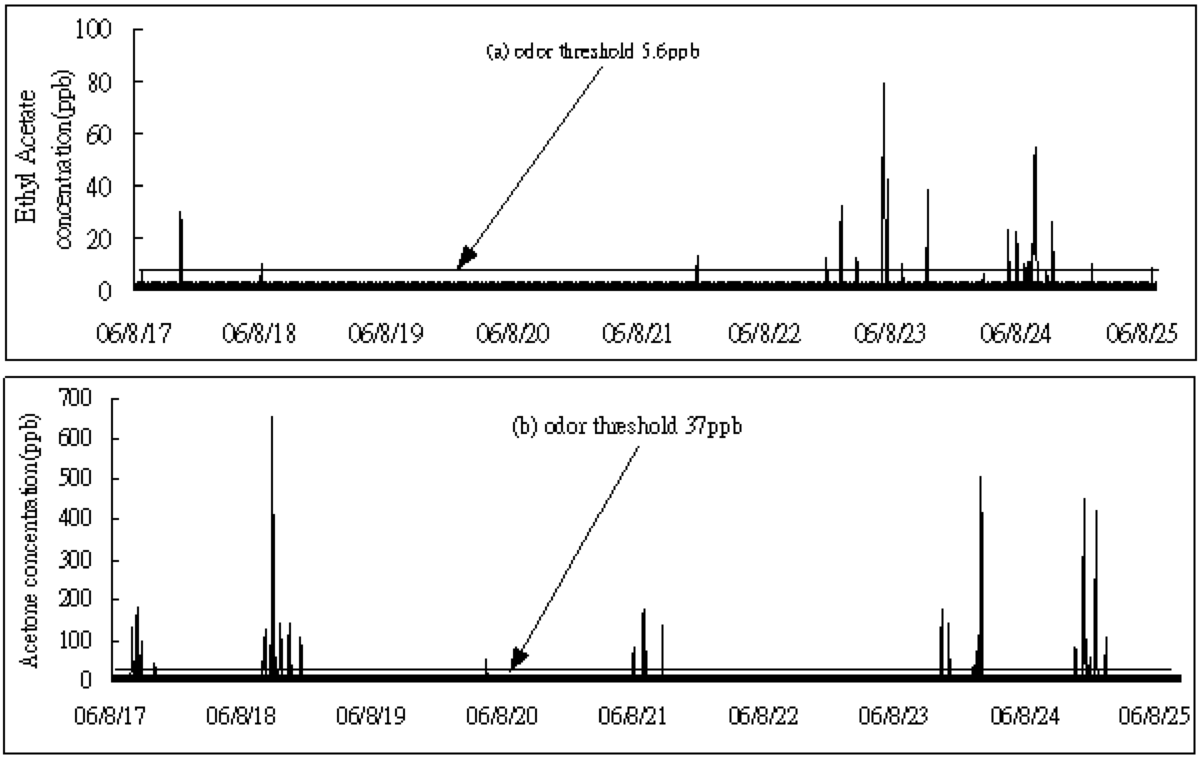


Figure 3. Variation of concentrations for both (a) ethyl acetate and (b) acetone inside the plant.

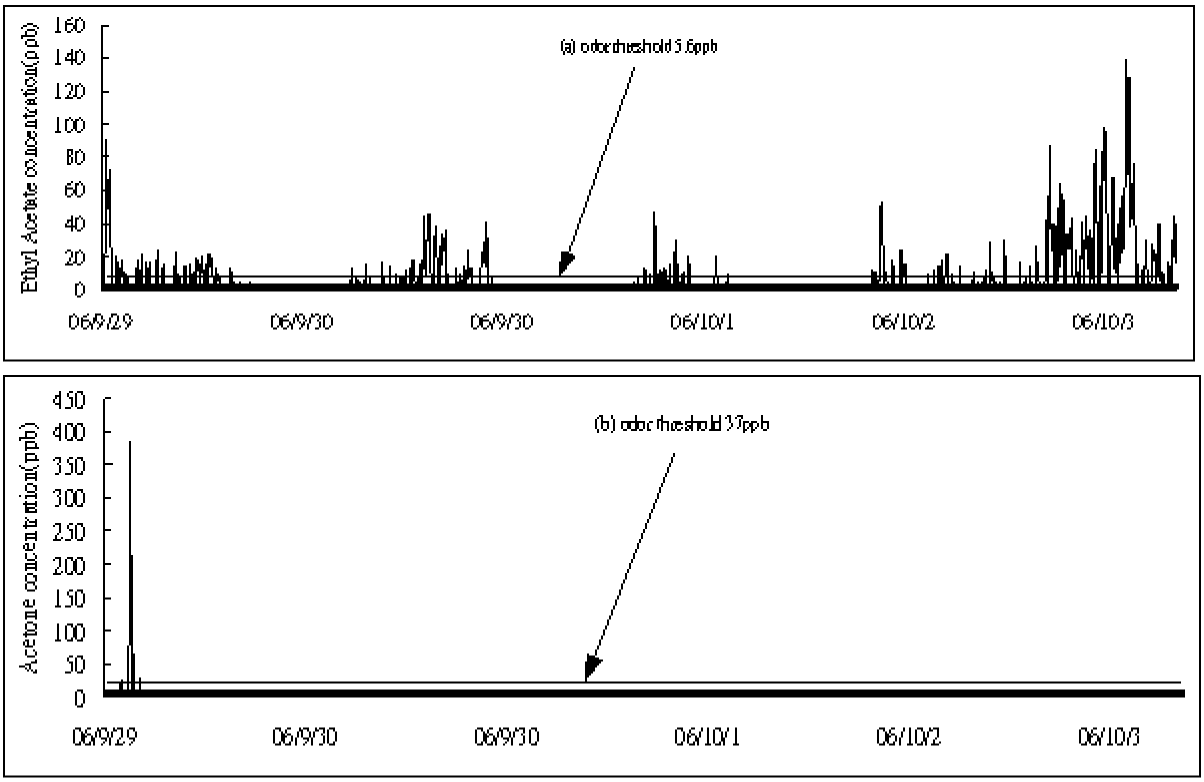


Table 1. OP-FTIR detected results (350m away) (2006/8/17~2006/8/25)

Species	Molecular formula	Odor threshold (ppb)[12]	[1]Detected max.(ppb)	[2]Detected min.(ppb)	[3]Detected probability (%)	[4]Exceeded threshold probability (%)	Standard deviation	Appearance	Sense of smell
Methanol	CH_3OH	3300	1175.79	0.17	48.48	0	127.68	Colorless liquid	Faintly sweet pungent odor like ethyl alcohol
Ethyl Acetate	$CH_3COOC_2H_5$	5.6	78.82	1.17	3.47	82.46	4.49	Colorless liquid	Fragrant, fruity odor
Acetone	CH_3COCH_3	37	655.53	2.89	4.57	92	33.75	Colorless liquid	Somewhat aromatic
N,N-Dimethyl Formamide	C_3H_7ON	470	284.69	0.47	8.65	0	20.88	Colorless liquid	Fishy, pungent
Isopropanol	$CH_3CHOHCH_3$	1000	533.05	22.08	1.46	0	16.39	Clear liquid	Slight alcohol odor
2-Butanone	C_4H_8O	250	70.25	36.73	0.24	0	2.40	Colorless liquid	Acetone like odor
Ammonia	NH_3	43	143.96	0.06	24.60	3.22	8.43	Colorless gas	Strong pungent odor
Chlorodifluoromethane	$CHClF_2$	Not Established	21.06	0.38	1.83	---	0.78	Colorless gas	Sweet odor
Cyclohexane	C_6H_{12}	520	23.99	0.82	1.10	0	1.01	Colorless liquid	Solvent odor

[1] Detected max.(ppb): Highest detected concentration as ppb.
[2] Detected max.(ppb): Highest detected concentration as ppb.
[3] Detected probability (%): Detected numbers divided by total monitoring numbers for certain pollutant
[4] Threshold probability (%): The number greater than odor threshold divided by detected numbers

Table 2. OP-FTIR detected results (inside the plant) (2006/9/29~2006/10/3)

species	Molecular formula	Odor threshold (ppb)[12]	[1]Detected max.(ppb)	[2]Detected min.(ppb)	[3]Detected probability (%)	[4]Exceeded threshold probability (%)	Standard deviation	Appearance	Sense of smell
Ethyl Acetate	$CH_3COOC_2H_5$	5.6	139.11	0.16	29.73	83.70	15.30	Colorless liquid	fragrant, fruity odor
Acetone	CH_3COCH_3	37	383.99	26.01	0.47	60.00	12.83	Colorless liquid	somewhat aromatic
Ethanol	CH_3CH_2OH	340	127.78	15.07	0.37	0.00	4.53	Colorless liquid	distinctive perfume-like odor
Methanol	CH_3OH	3300	84.75	0.02	23.77	0.00	11.63	Colorless liquid	faintly sweet pungent odor like ethyl alcohol
Ammonia	NH_3	43	20.85	0.02	35.69	0.00	2.31	Colorless gas	strong pungent odor
Chlorodifluoromethane	$CHClF_2$	Not Established	36.04	0.62	4.29	---	1.70	Colorless gas	odorless
Dichlorodifluoromethane	CCl_2F_2	Not Established	4.55	0.04	6.90	---	0.32	Colorless gas	odorless
Hexamethyldisiloxane	$(CH_3)_3SiOSi(CH_3)_3$	Not Established	0.29	0.01	2.52	---	0.01	Colorless liquid	odorless
t-Butyl acetoacetate	$CH_3COCH_2COOC(CH_3)_3$	Not Established	3.03	0.03	18.73	---	0.29	Clear yellow liquid	odorless

[1] Detected max.(ppb): Highest detected concentration as ppb.
[2] Detected max.(ppb): Highest detected concentration as ppb.
[3] Detected probability (%): Detected numbers divided by total monitoring numbers for certain pollutant
[4] Threshold probability (%): The number greater than odor threshold divided by detected numbers

Correlation of odor index and intensity

In order to understand the odor load in this area, odor was sampled with Tedlar bags simultaneously together with the OP-FTIR measurement applying the official test method of odor index from equation (1). In Table 3, samples were takes from upwind position (coordinate a) to downwind positions (coordinate b and coordinate c), where X and Y are their Universal Transverse Mercator (UTM) coordinates. Distances between two positions are also listed in the table. From Table 3, 11 out of 12 of the test results exceeded the odor standard 10 OU, indicating higher odor loads were observed in the downwind direction.

Table 3. Coordinate of sampled sites and odor index tested results.

Odor index	Coordinate a		Odor index	Coordinate b		Odor index	Coordinate c		distance(a,b)	distance(b,c)
	X	Y		X	Y		X	Y	m	m
80	291448	2763585	58	291349	2763432	48	291225	2763345	182.24	151.48
67	291458	2763484	63	291305	2763389	48	291241	2763299	180.09	110.44
78	291309	2763393	63	291253	2763330	63	291194	2763302	84.29	65.31
30	291107	2763279	14.5	291007	2763228	<10.0	290855	2763129	112.25	181.40

Odor intensity is defined as the ratio of pollutant concentration and odor threshold concentration, and the ratio exceeds 1 meaning the odor could be smelled. Since the fugitive odorants could transport to neighborhood by airstreams, the air pollutant dispersion was also depended on the meteorology condition. The every day meteorological data of the monitoring periods is shown in Table 4. In these two monitoring periods, the wind speed varied from 0.28 to 4.60 m/s per day, the wind direction varied from 30.08 to 240.46 degree and the temperature varied from 299.03 to 303.88 K. According to the monitoring results for the odor intensities and pollutants concentration, a statistical regression analysis between these two was conducted and listed in equation 2:

$$Y = 7.56 + 7.26X_1 + 5.86X_2 \qquad (2)$$

Where Y = odor index, X_1= ethyl acetate odor intensity, X_2= acetone odor intensity. With good coefficient of determination (R^2 = 0.9978), the above equation is able to represent the relations among the two critical pollutants and odor index, and the intercept 7.56 represents the background odor typically occurred in the environment.

Table 4. Meteorological conditions during the sampling periods.

Month	Day	Wind Speed (m/s)	Wind Dir. (Deg)	Wind Ref. Height (m)	Temp. (K)
8	17	1.78	240.46	6.1	303.88
8	18	0.85	125.00	6.1	300.62
8	19	1.53	74.13	6.1	301.64
8	20	2.60	39.50	6.1	302.21
8	21	1.67	55.04	6.1	301.73
8	22	2.13	58.50	6.1	300.74
8	23	0.38	50.92	6.1	300.02
8	24	0.28	30.08	6.1	300.39
8	25	1.12	73.46	6.1	302.35
9	29	4.60	46.29	6.1	299.88
9	30	4.25	47.08	6.1	300.08
10	1	3.75	53.75	6.1	299.79
10	2	3.28	61.38	6.1	299.05
10	3	3.16	57.04	6.1	299.03

Half-life time and AERMOD modeling

The above results were modeled using AERMOD to predict the fate of these pollutants and impact on the neighboring area. An important parameter in AERMOD, half-life time of odorant, was firstly determined. Theoretically, half-life time was depended on the temperature, humidity and windspeed. In this case study, with stable temperature and humidity, windspeed is the most important parameter if the pollutant being modeled is subject to first order exponential decay. Half-life time was determined by the following equations:

$$\frac{dC}{dt} = -kC \quad (3)$$

$$t_{1/2} = \frac{0.5C_0}{k} \quad (4)$$

Where $t_{1/2}$ is the half-life time, k is the rate constant and Co is the initial pollutant concentration. Using statistical linear regression analysis for each set of odor index result data, half-life time of odor index were obtained, where half-life time were 45.20-211.72 seconds with R^2 of 0.6013-0.9909, as shown in Table 5. The difference of half-life was contributed to the variation of windspeed mostly.

Table 5. Regression analysis equation and half-life of odor index.

first odor index	regression equation	R^2	half-life (second)
80	$y = 78.977e^{-0.0071x}$	0.9909	95.81
67	$y = 68.813e^{-0.0034x}$	0.9546	211.72
78	$y = 73.695e^{-0.0037x}$	0.6013	171.99
30	$y = 24.774e^{-0.0111x}$	0.8207	45.20

The derived half-life time was input into the AERMOD model to plot the pollutant dispersion route. Figure 4(a), (b) and (c) show the ethyl acetate, acetone and odor index dispersion route on 29th, September, 2006, respectively. For ethyl acetate in the Figure 4(a), each grid distance is 50m and the contour level is decreased from 300 ppb. For acetone in the Figure 4(b), each grid distance is 50m and the contour level is decreased from 400 ppb. For odor index in the Figure 4(c), each grid distance is 50m and the contour level is decreased from 300OU. The locations on the downwind about 50-100m accumulated the highest concentration approximately 2 multiples of original concentration and decayed gradually, as shown in the figures. The wind direction was northeastern in the monitoring period. Therefore, the contour level boundary on the downwind approximately 1025m would exceed the regulation of 10 OU and would affect the ambient residents. The measured and modeled results for odor index were compared in Figure 5. With the slope is very close to 1 (1.0086) and R^2 is 0.9794, the AERMOD can successfully simulate the dispersion routes of odor and pollutants and offer assistance to the government for managing the air pollutant emission.

Figure 4. Two-dimension concentration contour map of dispersion route: (a) ethyl acetate, (b) acetone, and (c) odor index

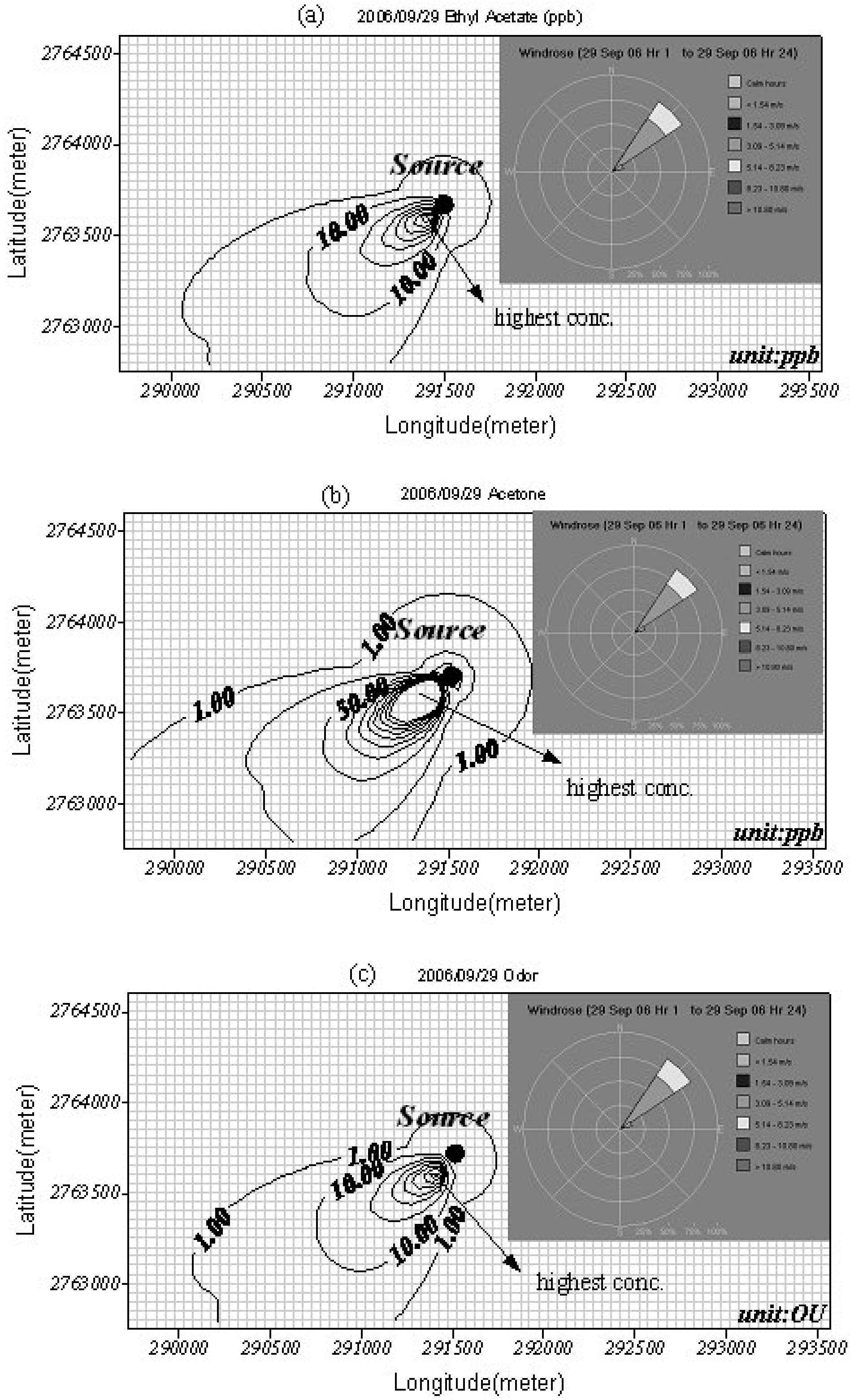
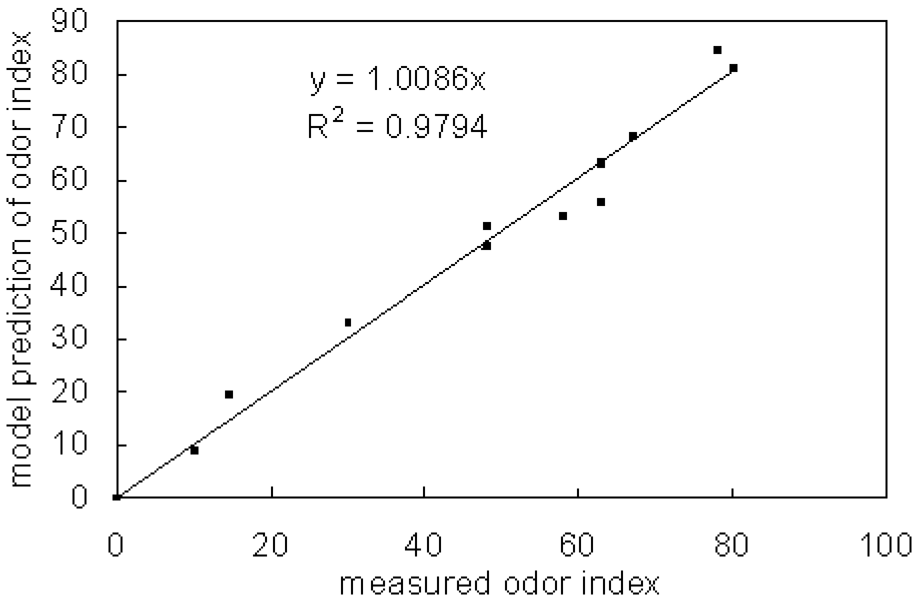


Figure 5. Actual measurements versus model predictions.



CONCLUSION

A case study was conducted to correlate the odor index and possible pollutants from a pharmaceutical plant based on the odor threshold and to model the results using AERMOD. Odor index and OP-FTIR were used to instantaneously monitor the odor and pollutants came from the pharmaceutical plant. The results showed, although nine different pollutants were obtained from OP-FTIR, the contribution to the detected odor was various due to their different odor thresholds. Consequently, only pollutants with odor intensity ≥1 were used to correlate with the odor index. Odor intensity of pollutants is defined as the concentration of each pollutant divided by the odor threshold. Consequently, a linear regression equation with correlation of determination (R^2) of 0.9978 was derived between the odor index and the odor intensity of pollutants. Moreover, AERMOD was used to model the odorant dispersion route to identify the influenced area. Half-life time in the AERMOD was firstly determined through the regression analysis of the odor index to derive the exponential decay equations between sampling sites, and the half-life time were obtained as 45.20-211.72 seconds with R^2 of 0.6013-0.9909. The influenced contour for odor index and each pollutant was then obtained by AERMOD and a good correlation was observed between the AERMOD predictions and the actual measured values. From the combination of OP-FTIR/AERMOD, this approach can not only quickly identify the odorant and estimate the pollution profile, but also offer recommendation to the government and the manufacturers for improving air pollutant emission.

ACKNOWLEDGMENT

The authors acknowledge the financial support from Taipei County Environmental Protection Bureau and OP-FTIR analysis from Industrial Technology Research Institute of

Taiwan, R.O.C.

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