行政院衛生署食品藥物管理局委託科技研究計畫

99 年度

「食品器具包裝不沾鍋塗層使用加工助劑全氟辛酸之溶出情形調查及健康風險評估」

年度研究報告

計畫編號：99TFDA-TC-102

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執行單位：中國醫藥大學 公共衛生學院 健康風險管理系

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中文摘要

全氟辛酸(Perfluorooctanoic acid, PFOA)為不沾鍋及防油紙塗層(Coating)的關鍵化工原料。美國環保署(USEPA)諮詢委員會於 2006 年提出「全氟辛酸安全評估報告」，建議歸為 B 類之「可能致癌物」，復於 2009 年訂定飲用水之暫行管制限值 0.4 ppb。2009 年 5 月斯德哥爾摩公約(Stockholm Convention)會議，將全氟辛烷磺酸及其鹽類和全氟辛基磺醯氟(Perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride, PFOS)增列為「持久性有機污染物(Persistant organic pollutants, POP)」，列於 Annex B (Restriction)－限制其製造與使用。許多研究亦顯示 PFOA 已普遍存在於各種環境介質、日用品與食品，亦發現人類血液中濃度為 10-300 ppb。美國 EPA C8 及歐盟 REACH 方案已訂定排放削減及物質減量、停產或工業限制之時程。

本研究目的為針對不沾塗層鍋具及防油紙，建立 PFOA 室溫及高溫遷移試驗方法及 HPLC/MS/MS 定量分析方法，可符合 USFDA 品管基準：全程擬似標準品回收率(R)60-110%及相對差異(RPD)<20%；上機液定量極限(LOQ)0.2 ng/mL (0.004-0.068 ng/cm^2)。室溫甲醇遷移結果：不沾鍋 ND-0.021 ng/cm^2 ，防油紙 ND-0.99 ng/cm^2。高溫模擬油遷移：不沾鍋及防油紙均為 ND，顯示 PFOA 不易於高溫油中溶出。高溫遷移後再室溫甲醇遷移：不沾鍋 ND-0.0078 ng/cm^2，防油紙 0.24-0.37 ng/cm^2 ，說明使用後再溶出之可能。

本研究建立一個 3-暴露路徑之風險評估模式，將"食品+飲用水"(ER_{fw})以及"非食品"(ER_{nf})暴露路徑，以保守情境估算二者佔總 TDI (1500 ng/kg-d) 最大比例：ER_{nf} 為 27%；ER_{fw} 為 50-70%。模擬結果顯示於保守情境下，在三個族群中，由於 BW 與 IR 的差異，青少年 (7-18 歲)有最低的第 50 百分位數(P50)特定遷移限值(SML)；而成年人 (19-59 歲)第 95 百分位數(P95) SML 低於青少年及年長者(+60 歲)。建議我國不沾鍋及防油紙之 PFOA 特定遷移管制限值採用成年人 P95：SML_p=2.4 ng/cm^2，SML_o=1.0 ng/cm^2。本研究常溫甲醇及高溫遷移結果均未超過該限值。本研究進一步以合理法推估歐盟及美國 PFOA 管制限值：1 ng/cm^2 (塗層)、0.2 ng/cm^2 (食品)，本研究風險評估結果與歐美推估值相當。

關鍵詞：全氟辛酸(PFOA)、遷移試驗、健康風險評估、特定遷移限值(SML)

英文摘要

Perfluorooctanoic acid (PFOA) is a key chemical in the coating of non-stick cookware and oil-resistant food paper. In 2006, A United State Environmental Protection Agency (USEPA) Advisory Committee proposed to classify PFOA as a Class B "Likely to be carcinogen" in a PFOA safety assessment report. In 2009, USEPA promulgated a provisional limit of 0.4 ppb for drinking water. In 2009, the Stockholm Convention decided to list perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride (PFOS) under Annex B, i.e., restricting its production and use. Many studies also reported that PFOA has widely occurred in various environmental media, commercial articles and foods. Human blood was reported to have a PFOA concentration of 10-300 ppb. USEPA's C8 stewardship and EU's REACH program has mandated regulatory schedules for the reduction or restriction of PFOA-containing materials or articles.

The objective of the study is to perform a surveillance program for the non-stick cookware and oil-resistant food paper and to propose a migration test and HPLC/MS/MS analysis for PFOA, meeting USFDA's quality control criteria: recovery check surrogate standard (RCSS) 60-110%, relative percent difference (RPD)<20% and limit of quantification (LOQ) 0.2 ng/mL for injection sample (0.004-0.068 ng/cm^2 for article sample). Results of migration test for cookware and food paper are: ND-0.021 and ND-0.99 ng/cm^2 at room temperature with methanol; all ND at high temperature with oil; ND-0.0078 and 0.24-0.37 ng/cm^2 at the follow-up room temperature with methanol, implying the possibility of repeated migration.

This study proposes a 3-pathway risk assessment model, in which the exposure dose ratios (ER) of the two pathways via "food plus drinking water" and "non-food" relative to the tolerable daily intake (TDI = 1500 ng/kg-d) are maximized: giving an ER of 27% and 50-70%, respectively. Due to the difference in body weight (BW) and intake rate (IR) among the three age-groups under study, the 50 percentile (P50) of specific migration limit (SML) are determined to be the lowest for the younger group (yr 7-18), while P95 for the adult group (19-59 yr) with SMLp = 2.4 ng/cm^2 and SMLo = 1.0 ng/cm^2, comparable to the SML of 1 ng/cm^2 (coatings) with European Union and 0.2 ng/cm^2 (food) with USFDA, both estimated by this study. All the migration data analyzed are below the SMLvalues suggested by this study.

keywords : PFOA, migration test, health risk assessment, specific migration limit (SML)

名詞縮寫與全名對照

ADD： 均日劑量(Average Daily Dose)

BMD： 基準劑量(Benchmark dose)

CEDI： 累計每日攝食量(Cumulative estimated daily intake)

CF： 物件材質消費係數(Consumption Factors)

CFSAN：食品安全及應用營養中心(Center for Food Safety and Applied Nutrition)

DC： 食品濃度(Dietary concentration)

DCL ： 食品濃度限值(Dietary concentration limit)

EC： 歐盟委員會(European Commission)

EU： 歐洲聯盟(European Union)

EDI ： 每日攝食量(Estimated daily intake)

ER： 各路徑暴露劑量比例(Exposure Ratio)

FSM： 食品接觸物件(Food Contact Material)

FCS ： 食品接觸物件(Food Contact Substance)

LOD： 偵測極限(Limit of detection)

LOQ： 定量極限(Limit of quantitation)

MAC： 可容許最大濃度(Maximum Acceptable Concentration)

MC： 遷移量(Migration Concentration)

NOAEL：無顯著危害效應劑量(No observable adverse effect level)

OML： 全遷移限值(Overall migration limit)

PFOA： 全氟辛酸(Perfluorooctanoic acid)

PFOS： 全氟辛烷磺酸(Perfluorooctane sulfonate)

POPs： 持久性有機汙染物(Persistent organic pollutants)

PHA ： 暫行標準值(Provisional Health Advisory)

RCSS： 回收查核擬似標準品(Recovery check surrogate standard)

RSD： 相對標準偏差(Relative standard deviation)

RPD： 相對差異百分比(Relative percentage difference)

SML： 特定遷移限值(Specific Migration Limit)

TDI： 每人每日耐受量(Tolerable Daily Intake)

UF： 不確定係數(Uncertainty Factor)

一、前言

全氟辛酸(Perfluorooctanoic acid, PFOA)為不沾塗層鍋具和防油紙之關鍵化工原料，美國環保署科學諮詢委員會建議將其列為 Class B 可能致癌物(EPA, 2006)。PFOA 具有生物累積性，可在人體內存留長達數年，一般人血清 PFOA 為 5-10 ppb，職業暴露勞工可高達 30-50 ppb，美國環保署 C8 大型流病調查結果顯示血清 PFOA 與血膽固醇之低密度脂蛋白(LDL)有正相關(Stephanie et al., 2010)。全氟辛烷磺酸(Perfluorooctane sulfonate, PFOS)及 PFOA 類化合物是二種持久性強的全氟類化合物(PFC)，由於其極佳的化學阻抗性及界面活性，此等化學物質廣泛的使用在工業及各種商品上，如膠帶、化妝品、清潔劑、塗料及電子產品等，因此，可能的暴露途徑，來源眾多。

不沾鍋塗層於合成時會使用 PFOA 作為加工助劑，PFOA 於聚合反應完成後會被回收再利用或破壞，一般認為可能殘留之含量應極微少，然而部分業者加工方式或品管不良，或不沾塗層多次使用後剝落者，是否會使PFOA暴露風險增加，仍有待探討。另日常用品像披薩盒與微波爆玉米花袋子等各種防油紙袋也曾發現含有 PFOA。

2009 年 5 月斯德哥爾摩公約(Stockholm Convention)會議(SCPOP, 2010)，正式將 PFOS 新增為列管之持久性有機汙染物(Persistent organic pollutants, POPs)，並歸類於 Annex B (Restriction)，限制其製造與使用。由於 PFOA 與 PFOS 結構及性質相近，為保障民眾飲食衛生安全，並避免疑慮，故本研究針對不沾塗層鍋具及防油紙可能含有之 PFOA，研擬遷移試驗及檢驗方法，進行市場採樣與調查，以釐清其食品安全問題，並建立風險評估模式，設定暴露情境，進行保守情境之健康風險評估，估算並建議不沾鍋及防油紙之特定遷移限值(SML)之管制限值。

二、文獻資料蒐集分析

2.1 先進國家 PFOA 及 PFOS 食品接觸物件安全管理規範

美國食品藥物管理局(FDA)定義食品接觸物質(Food contact substance, FCS)為任何用以製造、包裝、輸送或盛裝食品物質之成份，且非刻意添加者，提供添加成份之業者應提送 Food contact notification (FCN)；若 FCS 屬於法定食品添加物 (Food additive)，則業者應提送 Food additive petition (FAP)。兩項送審之管制指引為 "Guidance for Industry: Preparation of Premarket Submissions for Food Contact Substances: Chemistry Recommendations" (USFDA, 2007)，該指引係由隸屬於 FDA 之「食品安全及應用營養中心」(Center for Food Safety and Applied Nutrition, CFSAN) 所訂定，於 2002 年 4 月首度公告，目前最新版本公告於 2007 年 12 月，該指引係為本研究關鍵文件，故將全文列於本報告附件 A。該指引係作為業者準備 FCS 送審文件時之參考，但並非強制性之規範 (Nonbinding recommendations)，即業者若有更適當之評估方法，可不採用本指引。該指引不僅規範直接之 FCS，也規範間接其前驅物(Precursor)或非刻意添加之不純物(Impurity)。

根據該 USFDA 之指引，業者送審時應繳交之數據如表 1 共 6 項。若物件為容器類，可直接注入食品模擬物(Food simulant)，其選用原則如表 2 所示，若為平板類，可使用 One-sided migration cell，若未能溶出足夠量，可使用 Two-sided migration cell (Total immersion)，任何遷移試驗需有適當攪拌，以免受到物件局部之溶解度的限制。

假設食品與物件接觸係數之慣用值為 10 g food/in^2 (=155 g/dm^2)，考量四種食品模擬物之日常使用比例(Food-type distribution factor, f_T) (如表 3 所示)，計算食品中 FCS 之濃度 (Dietary concentration, DC)：

$$DC, mg/kg \text{ or } ppb = \Sigma[(MC_T, mg/in^2)(in^2/10\ g)(10^3 g/kg)\times(f_T)]$$

再假設每人每日食物攝食量 3 kg food/head-day，平均體重(Body weight, BW) 60 kg，考量物件材質消費係數(Consumption factor, CF)，如表 4，可計算每日攝食量(Estimated daily intake, EDI)如下，表 5 為一計算例：

$$EDI, mg/kg\ bw\text{-}day = (DC, mg/kg)(3\ kg/head\text{-}day)(head/60\ kg\ bw)(CF)$$

此外，FDA 之「食品添加安全局」(Office of Food Additive Safety, OFAS)也

建立一網站資料庫，供業者查詢各 FCS 之 DCL 與 CEDI 管制限值，目前該資料庫共列管 1267 種 FCS，PFOA 之管制限值為：食品濃度(Dietary concentration, DC) 0.12 ppb (μg/kg)及累計每日攝食量(Cumulative estimated daily intake, CEDI) 6 ng/kg-day，但尚未規範 PFOS 之限值，根據該資料庫說明，若未規範者，可暫定為 DC = 7 ppb, CEDI = 350 ng/kg bw-day，較 PFOA 寬鬆，因 PFOS 毒性較 PFOA 強，本研究認為並不適用 PFOS。

歐盟塑膠 FCS 遷移試驗指引(EU, 2004)共規範 17 類不同塑膠物質：Adhesives, ceramics, cork, rubbers, glass, ion-exchange resins, metals and alloys, paper and board, plastics, printing inks, regenerated cellulose, silicones, textiles, vanishes and coatings, waxes, wood。管制限值乃根據每日耐受量(Tolerable daily intake, TDI)，假設終身暴露、體重 60 kg、每日攝食 1 kg 食物、食品接觸係數 1 kg/6 dm^2 (=167 g/dm^2)，所計算的特定遷移限值(Specific migration limit, SML)，除此之外，對於同類型之各種 Food contact material (FCM)，亦要求符合全遷移限值(Overall migration limit, OML)，但其 SML 及 OML 之單位為 mg/kg，故應解釋為食品中之污染物濃度限值，即相當於 USFDA 之 DCL。PFOA 之物質編號為 No. 00468，屬於第 9 類 Plastics 之 Additive (9.1)，目前已列管 853 種 FCM，但尚未訂定 SML，唯一值可參考之文件係歐盟之 PFOS 管制指令(2006/122/ECOF)，如附件 B。其中規定物件塗層含量不得高於 0.1 ng/cm^2 之 PFOS，因 PFOA 之 TDI 為 PFOS 之 10 倍，可推估 PFOA 之管制限制為 1 ng/cm^2。

綜合上述討論，圖 1 比較美國與歐盟兩國之 FCS 管制方式，有相當大的不同，美國將遷移濃度 MC 換算為食品濃度 DC 與每日攝食量 EDI，再分別與管制限值 DCL 與 CEDI 比較。而歐盟於已知 S/V 時，以實際使用 S/V 定量溶媒，將 EC (mg/L)換算為 MC (mg/dm^2)，再以食品接觸係數 1 kg/6 dm^2 將 MC 換算為 mg/kg，再與 SML 管制限值比較；當 S/V 未知時，以 1 kg/6 dm^2 定量溶媒體積，所得之 EC 即為 MC (mg/kg)，可直接與 SML 比較。SML 單位為 mg/kg，相當於 USFDA 之 DCL，故若 MC 之濃度為 mg/dm^2 時，應將單位換算為 mg/kg，再與 SML 比較。歐盟另要求同類型 FCS 亦須符合全遷移限值 OML(=60 mg/kg)，我國目前訂定之標準限值(食品藥物管理局，民 93 年)為遷移濃度或溶出濃度，尚待釐清。

加拿大衛生署食品研究處(HCFRD, 2009)於官網上宣稱食品包裝不是食品中

PFC 的重要來源，加拿大於 2006 及 2007 的 TDS 計畫，調查肉品、魚類食品及包裝過之食物，結果顯示無足夠數據可確認是否有某類食品普遍含有 PFC，另經試驗調查，經過烘烤、水煮及煎炒魚類及貝類，可減少 PFC 濃度 54-100%。目前加拿大與英國的食品調查顯示，PFC 之濃度約為 ppb level (ng/g)，北美大人及小孩血液中均可廣泛偵測到 PFC，說明食品為重要暴露路徑，2004 年之 CTDS 調查估計食品 PFOA 暴露劑量為 4.0 ng/kg-d，尚未健康疑慮。另加拿大政府已將 PFOS 列入 Canadian Environmental Protection Act 之 Toxic Substance List，並已提出 Risk Management Strategy，以減少或削減 PFOS 排入環境中。

日本 Japan External Trade Organization (JETRO, 2009)發布"Specifications standards and Testing Methods for Foodstuffs, Implements, Containers and Packageing, Toys, Detergents"，這是依據日本 Food Sanitation Law (NO.233, 1947) 第 7 及第 10 條所訂定的。該檢驗規範與標準共分四章，其中第二章係有關本研究之食品器具、容器與包裝，其中規範該物件水溶出液之過錳酸鉀(Potassium Permanganate)的氧化消耗量、抗壓力與接縫試驗、原子吸光(AA)光譜儀分析及蒸發殘留試驗(Evaporation Residute Test)，後者規範四種溶媒之選用：Heptane(油性食物)、20% ethanol(酒精性)、Water (pH>5 食物)及 4% HAc (pH≦5 食物)，與我國規定一致。在該方法 D-2 節中，規範了合成樹脂食品接觸物件的試驗方法，包括 Melamine resin 及 Phenol resin 及 Vrea resin 的合成材料。值得注意的是在日本使用"Elution test"，代表歐美之 Migration Test，一般會規範溶媒種類、溶媒體積、樣品質量、暴露溫度與時間及檢驗方法與法規安全限值等，但尚未對 PFOA 或 PFOS 訂定相關規定。

2.2 國際間 PFOA 遷移試驗方法

美國 FDA 要求進行遷移試驗時，應提供受測試體(Test plague)之化學配方(Formulation)、厚度與表面積，若採全浸泡，或試體厚度>0.05 cm 且遷移量<25% 理論值，各面可視為單獨遷移，暴露面積以雙面計算，否則採單面計算；但紙類遷移受限於溶解度(Solubility)，而非擴散(Diffusion)，所以不論厚度，均應以單面計算。進行遷移試驗時，應視實際情形，採用最嚴格的暴露溫度與時間(短暫暴露)，若為貯存容器，可採用 40 °C 及 10 天，以加速模擬室溫(20 °C)及 6-12 月之長期貯存，每食品模擬物應執行三重複遷移試驗，遷移濃度(Migration

concentration, MC_T)結果採平均值，單位表示為 mg/in^2 或 mg/dm^2。三重複遷移試驗中各添加 1/2、1、2 倍之 Surrogate Standard，結果取平均值，若試驗結果 DC≦0.1 mg/kg，回收率(R) = 60-110%，相對標準偏差(RSD) <20%，若 DC>0.1mg/kg，R=80-110%，RSD<10%，對於本研究之遷移物件而言，可將該 DC 換算為 MC，以利研判食品接觸物件回收率及 RSD(或 RPD)之品管要求，詳參本報告之結果與討論。

美國環保署調查 116 種商品物件(Article of commerce)之 PFOA 遷移試驗(USEPA, 2009)，不沾鍋之試驗程序：(1)以 Surrogate RCS 添加之 methanol 100-150 mL 浸泡鍋面約 0.3 mm 深； (2)鍋面以 Aluminum foil 密封避免蒸發； (3)於室溫萃取 24 hrs； (4)蒸餾濃縮至約 1 mL。防油紙之試驗程序：(1)以不銹鋼刀切割樣品約 1 g (5×5 cm)； (2)將樣品置入 Surrogate RCS 添加之 45 mL methanol 之 50 mL PE 離心管中； (3)以 Nutating mixer 於室溫萃取 24hrs； (4)蒸餾濃縮至約 1 mL。所有物件需執行 2 重複之遷移試驗，結果取平均值，試驗結果：不沾鍋 1- 50 $\times 10^{-3}$ ng/cm^2, 防油紙 2-420 ng/g。

歐盟遷移試驗以單面暴露為原則，亦可採用更嚴格之切片(0.6 dm^2)全浸泡(Total immersion)，比表面積採用慣用值 S/V=6 dm^2/L，且僅能以單面面積計算，而對稱性物件可計算雙面面積，切口厚度 > 0.5 mm 時，切口可以併入暴露面積。食品模擬物有四種 Simulant A, distilled water; B, 3% HAC; C, 10% ethanol, D, rectified olive oil。若 S/V 已知，且容器體積<0.5 L 或>10 L，屬容器類計算單位以 mg/dm^2 (M) 表示，非屬容器類以 mg/kg (C)表示，但 C 應換算為 MC 再與 SML 比較。英國與中國(2009)之指引完全參考此一指引，表 6 為整理自中國(2003)浸泡試驗通則之 SML 計算公式，對於扁平容器，物件表面積每 cm^2 須使用 2 mL 之溶媒，測得之遷移濃度可以表示為 mg/L 或 mg/dm^2，惟前者容易與溶出濃度混淆。

表 7 整理比較文獻中不沾塗層鍋具及防油紙之遷移試驗條件，除了 Begley et al. (2005)外，其他不沾鍋研究均使用原型鍋具盛裝法，USEPA(2009)之室溫甲醇遷移著重於建立物件之製造品質篩檢法，而其他研究嘗試模擬可能之調理條件，高溫模擬調理之溫度為 50-160°C，肉類調理時之最高溫度約為 130-160 °C，超過 220°C 不沾塗層會開始燃燒裂解。值得注意的是，USFDA(2007)乃針對單體業者(非物件廠商)，對於每一項申請要求進行 4 種 food simulant 之遷移試驗，再將各

種遷移濃度乘以各種 food simulant 之消費係數，加總之後得出加權平均之遷移濃度。

2.3 國際間 PFOA 溶出量分析檢驗方法

表 8 比較文獻中不同商品物件(Article of commerce, AOC)或食品接觸物件(Food contact article, FCA)之檢測方法，一般而言，因為物件樣品基質較食品或土壤樣品之基質單純，其前處理程序較為簡單，樣品種類包括鍋具、防油紙、織品、膠帶、地毯等，對於容器物件(如鍋具)，一般採原型盛裝法遷移，單位表示為 ng/cm^2；對於平板樣品(如防油紙、地毯)，則將樣品切割成約 1 g，採用全浸泡法，遷移單位表示為 ng/g，也可利用該物件之表面密度(g/cm^2)，將該單位換算為 ng/cm^2，但 Begley et al.(2005)以鋼刷將鍋具塗層刮成粉末後，再以全浸泡法進行遷移試驗，其遷移濃度會較原型遷移者高出甚多。

各研究使用之溶出條件也有不同，USEPA(2009)採用甲醇為溶媒，於室溫下暴露 24 hrs，其他研究嘗試模擬食品調理條件，使用食品油或奶油於高溫下進行遷移試驗暴露溫度為 50-130℃，暴露時間 10-15 min。因為考量溶出量屬於 ppb 級，文獻中各分析方法均採用高效液相層析串聯質譜儀(HPLC/MS/MS)，但因 PFOA 之分析極易受背景干擾，所有研究均說明必須先進行全方位的背景干擾排除，包括 Teflon 管線、墊片、溶劑、蒸餾水、及容器等可能之干擾查核。詳細內容請參考本報告結果與討論之相關章節。

在質譜儀分析中，PFOA 之鑑定方式大多使用母離子 413 與子離子 369 之 m/z 比及滯留時間為判斷基準，但 Bononi and Tateo (2007)另增加一組子離子 168 為判斷基準。上機液定量極限(LOQ)一般可達 0.2 ng/mL (ppb)，物件之 LOQ 可達 0.06-0.1 ng/cm^2 或 0.5-5 ng/g，回收查核擬似標準品(Recovery Check Surrogate Standard, RCSS)之回收率可達 60-120%，一般而言，樣品基質愈單純(如甲醇、水)，RCSS 之回收率可以愈高，但若使用食用油或奶油，回收率將會降低，同時遷移濃度愈低者，回收率也會降低。

2.4 國內外 PFOA 食品接觸物件溶出背景資料

表 9 比較文獻中不沾鍋及防油紙各種遷移試驗條件及遷移濃度。美國 FDA 對 PFOA 進行遷移研究(Begley et al. 2005, 2008)，將微波爆米花紙袋微波加熱 2

min 後，裁成 11.7 dm^2 大小樣品，以模擬合成油進行高溫全浸泡式遷移，以 LC/MS/MS 檢測遷移濃度，結果顯示 PFOA 濃度範圍 6-290 μg/kg，若乘以本研究規估之面積密度 0.02 g/cm^2，可換算為 0.12-5.8 ng/cm^2。另將不沾塗層鍋具(重量 588 g，鍋具直徑 28 cm)空燒，以鋼刷刮取其不沾塗層粉末，以甲醇為溶媒，於 50°C/24 hr 的條件下進行遷移試驗，以 LC/MS/MS 檢測遷移濃度。Begley et al. (2008) 針對爆米花紙袋、漢堡紙袋和比薩盒等防油紙進行各種條件之高溫遷移試驗。速食產業大量使用防油紙作為盛裝或包裝食品的器具，會造成短時間的食品高溫暴露，圖 2 為三種結構的 Perfluorochemicals(PFC)在四種標準食品模擬物(水、醋酸、酒精、模擬合成油及奶油)作為溶媒之遷移試驗結果，遷移條件為模擬防油紙高溫短時間接觸食品之情形，將溶媒預熱至 100°C 後，在室溫下與防油紙暴露 15 min，防油紙自美國一般市場採樣取得，高溫暴露試驗結果顯示一般的合成油(Miglyol)之三種 PFCs 的溶出濃度為 0.01-0.05 mg/kg (0.2-1 ng/cm^2)，為方便與本研究結果比較，經由本研究估算之防油紙表面積密度 0.02 g/cm^2 ，將文獻原始值單位換算為 ng/cm^2，其他三種食品標準模擬物在兩種結構之 PFC 較高，約為 0.01-2 mg/kg (0.2-40 ng/cm^2)，值得注意的是，以奶油(Butter)作為溶媒時，其遷移濃度(mg/kg)高出其他四種標準食品模擬物達 1.5-60 倍之多。圖 3 係該研究使用非標準食品模擬物進行之室溫遷移試驗結果，顯示離子性乳化劑及非離子性乳化劑(80%油＋20%水)、合成油(Miglyol)、合成油含離子性乳化劑及非離子性乳化劑、奶油以及巧克力醬等六種食品模擬物於 40°C，暴露 24 hr 之情形下，進行三次獨立試驗之平均值。該研究使用的離子及非離子性乳化劑係 Soy lecithin 及 Polysorbate 60，研究發現即使於合成油中僅添加含少許乳化劑(1%)，也會大幅增加遷移的濃度，例如合成油添加 Soy lecithin (離子性乳化劑)的遷移濃度是純合成油的約 50 倍。可見欲評估真正遷移情況，食品模擬物的選擇與調理條件非常重要。

2005 年美國杜邦公司(Powely et al., 2005)為模擬實際烹調情形和食物特性，分別以水和乙醇混合水溶液作為不沾塗層鍋具 PFOA 遷移試驗之溶媒，以盛裝方式在不沾塗層鍋具中加入水至距離鍋具上緣 0.6 公分處，使用特製配備高壓冷凝回流裝置之鍋蓋蓋上，以 100 °C 遷移 30 min；以乙醇混合水溶液為溶媒，將鍋具不沾塗層切為矩形，搭配高溫加壓萃取裝置採全浸泡式，於 125°C、1000 psi 的條件下靜置遷移 10 分鐘，最後以 LC/MS/MS 檢測遷移濃度，結果均低於偵測

極限，因作者代表杜邦公司，研究結果較不可信。

Bononi and Tateo (2007)進行模擬調理的遷移方法則是讓不沾鍋先使用過一次，製作一般家庭用番茄醬，材料為 2 顆番茄和 2 大匙橄欖油，再依鍋具廠商建議的方法將不沾鍋清洗乾淨後，分別進行兩種模擬調理遷移：以橄欖油為溶媒採盛裝方式，加熱至 120-160°C 於 10 min 後將橄欖油進行檢測；另以橄欖油為溶媒，採盛裝方式預先加熱後，倒入事先準備好之馬鈴薯棒熱炒 10 min，移除馬鈴薯棒後以橄欖油為溶媒溶出 PFOA。

美國環保署(USEPA, 2009) 以甲醇作為遷移試驗之溶媒，將 14 種不沾塗層鍋具以盛裝方式，5 種防油紙以全浸泡方式，於室溫下進行 24 小時之遷移試驗，以 LC/MS/MS 作為檢測儀器，測得不沾塗層鍋具之 PFOA 遷移濃度為 ND-0.05 ng/cm^2，防油紙之 PFOA 遷移濃度為 ND-4640 ng/g，乘以本研究估算之不沾塗層表面積密度 0.01 g/cm^2，約為 ND-92.8 ng/cm^2。綜合上述，防油紙的溶出一般而言較不沾鍋高出甚多，值得進一步探討。

2.5 國內外 PFOA 及 PFOS 食品濃度資料

本計畫爲了解國內外 PFOA 及 PFOS 於一般食品中之污染濃度，利用 PubMed, Web of Science 及 Ovid-Medline 等資料庫檢索，蒐集 18 篇 PFOA 及 PFOS 食品相關研究文獻。

2007 年 Tittlemier et al.研究 54 種食物中所含之 PFOA 及 PFOS 濃度，54 種食物樣品來自加拿大國家總膳食調查計畫(Total diet Study, TDS)計畫的一部份，該計畫從加拿大各個城市中的賣場和速食店取得食物樣品(1999-2004)再混合烹煮，檢測結果顯示 54 種食物中有 9 種可測得 PFAS，單位為 ng/g。尤其 PFOA 在烤牛肉、比薩和微波爆米花等項目之濃度較高，分別為 2.6、0.74 和 3.6 ng/g；PFOS 在肉類、魚類和微波爆米花分別為 0.5-2.7，1.3-2.6 和 0.98 ng/g，如表 10 所示。

由於微波爆米花紙袋內層經常塗佈 Teflon 材質，因此微波爆米花為 PFOA 之重點檢測樣品，表 11 顯示檢測五種市售爆米花微波後所含全氟化物(PFC)之濃度可高達 3900 ng/g，爆米花中之全氟化物應為自紙袋遷移溶出汙染所致。

將水產食品中 PFOA 及 PFOS 濃度資料依國家區域分為歐洲區、亞洲區和北美區，編列如表 12、表 13。PFOA 在此三個地區之濃度值分別為 0.1-53.0、0.2-22.9

及 ND-5.3 ng/g；PFOS 在此三個地區之濃度值分別為 1-520、0.1-47.2 及 0.08-99.5 ng/g，表中資料根據 EFSA (2008)建議均以乾重計算，或將原濕重資料換算為乾重，此與一般 TDS 所使用之"as consumed"不同。我國中央大學亦有此方面之研究(Tseng et al., 2006)，水產樣品為一般常見吳郭魚、日本鱸魚和牡蠣，採自桃園中壢魚市場和台南七股，後者為我國重要水產養殖地之一。樣品分析魚類分為肉質部位和肝臟部位，牡蠣則分為肉質部位和內臟部位，分析結果顯示 PFOS 濃度大於 PFOA，內臟、肝臟濃度大於肉質部位。由上述所呈現的資料中可以得知 PFOS 在水產食品中之濃度大於 PFOA。

2.6 國內外 PFOA 及 PFOS 環境背景資料

PFOA 及 PFOS 因其不易分解之特性而在環境中造成持久性污染，本計畫蒐集國內外環境中，包括水體、底泥、室內灰塵及一些日常用品之 PFOA 及 PFOS 背景資料。水體方面蒐集了國內外海水、河川及飲用水之背景濃度文獻如表 14、表 15 所示，綜觀各國水體之 PFOA 及 PFOS 測得濃度，尤以河川水體相差甚巨，Lin et al. (2009)於台灣河川中 PFCs 濃度之研究，發現 Keya River 樣品中測得之高濃度 PFOA(310 ng/L)與 PFOS(5440 ng/L)，樣品係採自於新竹科學園區排放於 Keya River 上流的工業放流水，該園區主要產業包括半導體、電子及光電產業，PFOS 為金屬電鍍、電子腐蝕槽的抑酸霧劑以及電子化學等方面應用，Xiaoli、Touchien 及 Keya Rivers 皆係接受這些產業所排放廢水之河川，比較其他國家亦有類似的情況，義大利北部的 Po 和 T'anaro 兩河川的 PFOA 濃度最高可能原因為設立在附近的含氟聚合物製造商；美國南部的 Tannessee River 亦是因為在當地設廠之氟化物製造商。日本、中國及德國河川中 PFOA 的濃度低於台灣河川，其原因為匯入該河川係城市廢水而非工業放流水。由此可見河川上游的來源是檢視 PFOA 及 PFOS 濃度的重要因素。台灣 Keya River 中 PFOA 及 PFOS 的高濃度需要加以警戒，但該河川的功能性造成 PFCs 高濃度並不能視為台灣河川的整體濃度。Lin et al. (2009)證實半導體及光電等工業是水體中 PFCs 的重要來源，並且也顯示出工業活動對地方及河川下游造成的重大影響。

美國調查 San Francisco Bay 地區河川及海灣淤泥中 PFCs 之濃度，另外收集 11 座廢水處理廠之工業汙泥進行分析檢測。不論河川、海灣淤泥或工業汙泥之 PFCs 檢測結果，PFOS 皆有明顯高濃度，濃度在 ND-2610 ng/g(表 16 僅呈現 PFOA

及 PFOS 濃度)。Nakata et al. (2006)於 Ariake Sea 地區灘塗淤泥，進行 PFCs 之濃度測定。特別是，該研究在灘塗淤泥中測得之 PFOA 濃度大於 PFOS。Becker et al. (2008)研究德國境內 PFOA 及 PFOS 於河川底泥中濃度，其樣品取自 Roter Main River，該河為工業、商業及家庭廢水處理廠之受納水體，同時供給 72,000 名居民使用。採樣點位於廢水處理廠上游及下游數個，測得底泥濃度下游高於上游約莫三倍，PFOS 濃度又高於 PFOA。比較美國、日本及德國的整體沉積底泥濃度，PFOS 幾乎都高於 PFOA，原因除了 PFOS 在工業中的應用外，也可能因著 PFOS 在水中溶解度大於 PFOA 之故。整理於表 16 之濃度數據均為乾重表示。

住家室內灰塵中 PFOA 及 PFOS 濃度如表 17 所示，不論是日本或是加拿大，PFOA 及 PFOS 濃度均有 ppm 等級，從 USEPA (2009)日常用品中的 PFOA 遷移濃度(表 18) 即可看出一般民眾生活中隨處可接觸的物件都可能為暴露來源，尤其地板、車子專用蠟和地毯專用防汙劑等積聚而成之粉塵，為室內灰塵中高濃度 PFOA 及 PFOS 的原因，本研究將使用日本 Moriwaki et al.(2003)之灰塵中 PFOA 濃度值，推估非食品暴露佔 TDI 之比例，作為風險評估的情境設定。

三、結果與討論

3.1 PFOA 檢驗分析方法建立

3.1.1 遷移檢驗方法及品管要求

附件 C 為本研究研擬之不沾塗層鍋具及防油紙 PFOA 遷移試驗方法，本方法之研擬參考「美國食品藥物管理局食品安全及應用營養中心」(USFDA, 2007)及歐盟(EU, 2004)之 FCS 遷移試驗一般性指引，及我國塑膠類之食品器具、容器、包裝檢驗方法(食品藥物管理局，93 年)。室溫遷移試驗條件參考 USEPA (2009)，高溫模擬調理遷移試驗條件參考 Begley et al. (2005, 2008)及 Bononi and Tateo (2007)。不沾鍋採盛裝法，試驗結果以 ng/cm^2 表示，防油紙採全浸泡法(Total immersion)，試驗結果以 ng/g 表示，亦可視管制上限標準之需要，將單位轉換為 ng/cm^2，但以單面防油紙面積計算。

USFDA(2007)規定若試體厚度＞0.05 cm，且遷移量＜25 %理論遷移量，各面視為獨立遷移，暴露面積以兩面計算，否則僅以單面計算。但對於紙類，其遷移量為溶解度驅動的(Solubility-driven)，所以不論厚度，均應以單面計算。另規定進行方法確效(Validation)時，材質業者於申請許可送件時，需查核準確性(Accuracy)及精確性(Precision)，包括(1)近似待測樣品濃度之基質標準品 (Marix standard)之重複分析；(2)基質標準品之回收率。同時，需於遷移試驗完成後，再將標準品加入萃出液中，該指引認為先將標準品加入溶媒中，可能為最大的共同確效查核缺失。

另外，為查核回收率，需進行三重複，其添加標準品濃度應為預期物件萃取濃度之 0.5、1 及 2 倍，且當食品或溶媒濃度檢驗結果＜0.1 mg/kg 時，回收率為 60-110 %，相對標準偏差(RSD)為＜20 %，若＞0.1 mg/kg 時，回收率為 80-110 %，RSD 為<10% (USFDA, 2007)，但在美國該品管要求係針對 FCS 的單體業者，其品質及確效要求較為嚴格，而本研究試驗之目的為評估各種市售食品接觸物件之製造業者，建議僅採集每一型號之物件各一件，分別進行遷移試驗後，將溶出液分樣(Split Sample)，其重複分析之相對差異百分比(Relative percentage difference, RPD)應小於 20%，結果以平均值表示，且使用全程添加之同位素擬似標準品(Recovery check surrogate standard)，其全程回收率應為 60-110 %。為了便於比對本研究之遷移濃度，可以利用下列方式將 USFDA (2007)所稱之食品中濃度之 0.1

mg/kg 換算為遷移濃度：

$$MC=(0.1\ \frac{mg}{kg-food})(10\ \frac{g}{in^2})(\frac{1\ kg}{1000\ g})(\frac{1\ in}{2.54\ cm})^2(10^6\frac{ng}{mg})=155\ ng/cm^2$$

因本研究試驗結果之遷移濃度均遠小於 155 ng/cm^2，故 Recovery 及 RPD 之品管要求分別為 60-110%及<20%。

3.1.2 溶出量檢驗方法及品管要求

本研究參考 USFDA(2009)及 Lu et al.(2009)之 PFOA 分析程序，使用液相層析串聯質譜儀分析法(High Performance Liquid chromatography/tandem mass spectrometry, HPLC/MS/MS)，研擬之方法初稿詳附件 D，食品接觸物件之遷移試驗程序詳附件 C 及前節，其中不沾鍋採盛裝法，而防油紙採浸泡法，以 HPLC 級甲醇於室溫萃取 24 hrs，再加入 PFOA 之同位素作為回收率查核擬似標準品(Recovery Check Surrogate Standard, RCSS)，吹氮濃縮至 1 mL，最後定容至 10 mL 後上機。

HPLC/MS/MS 之分析使用 0.2-10.0 ng/mL (ppb)之 5 個濃度標準品建立檢量線，使用 Agilent Model 1200 之 HPLC, 及 AB Model API 5000 之 ESI-MS/MS。層析管柱、保護管柱、動相梯度移動條件、電噴灑離子源及監測離子對等操作條件詳表 19 所示。相對離子強度之容許範圍參考歐盟(EU, 2002)之規範。表 20 為品質管制要求，其中 RCSS 回收率及重複樣品差異百分比(RDP)參考 USFDA(2007)，分別為 60-110%及<20%。回收查核擬似標準品添加量計算例如表 21，常溫甲醇遷移吹氮濃縮至 1 mL，高溫油品遷移吹氮濃縮至 2 mL，並以上機溶劑定量至 10 mL。各種樣品上機施打程序如表 22，樣品 1-5 為 5 點檢量線之建立，進行批次樣品前，施打樣品 6 再次確認檢量線，但需以不同於檢量線製作來源之標準品確認檢量線之適用性。再進行批次樣品施打，施打前依序再進行檢量線查核、方法空白、標準品查核，施打 10 個樣品或每一批樣品後，再進行一次檢量線查核。

3.1.3 背景干擾查核與避免措施

一般所使用之高效能液相層析串聯式質譜儀(HPLC/MS/MS)通常有 PFOA 之背景干擾，本研究首先注射上機溶劑(設備空白)，PFOA 背景干擾如圖 4 之(A)所示，PFOA 之訊號(位移 7.0-7.5 min)強度明顯，須加以排除，經更換 HPLC 之移動相溶劑抽取管及過濾器(PTFE 材質)，改以 1/8"不鏽鋼管替代，且溶劑抽取

過程中不連接溶劑除氣裝置，直接連結層析儀幫浦，幫浦內原 PTFE 材質的 pump seal 更換為 PE 材質，樣品瓶改用全 PP 材質之瓶身及瓶蓋，不使用含 PTFE 材質管線之移動相溶劑分注器，而直接倒出使用，移動相試劑水先以 C18 SPE 淨化後使用，而修改後設備空白之 PFOA 背景干擾如圖 4 之(B)所示，PFOA 之訊號強度已降低，訊噪比為 5.7，層析圖譜背景基線亦降低，而經注射 2 pg PFOA 之訊號(即本實驗檢量線最低點濃度 0.2 ng/mLx10μL)如圖 4 之(C)所示，訊噪比達 69.3 為明顯訊號，故以 0.2 ng/mL 為檢量線最低點濃度影響甚微；而前處理之容器均使用 PP 材質，移除吹氮濃縮設備氣體管線之 1/4"PTFE 材質管線，改以 1/4" 銅管替代，且移除 PTFE 鍍膜之吹氮針，改以不鏽鋼吹氮針替代，在遷移萃取所使用之溶劑甲醇，同樣不使用含 PTFE 管線之溶劑分注器，而直接倒出使用，且在每批次實驗執行一組方法空白樣品，以確認分析過程未受到污染。表 23 整理本研究上述之各項消除背景干擾之措施。

3.2 PFOA 溶出量檢驗結果

3.2.1 採樣調查結果

本計畫於台中市去隨機採集不沾塗層鍋具及防油紙各 15 件，台中市為中部 6 縣市民眾的消費都會區，消費型態具有全國代表性。15 件不沾塗層鍋具皆採集自各大知名賣場，如大潤發、愛買及台糖量販店。15 件防油紙來自各大賣場以及坊間店家使用之產品，坊間店家包括一般早餐店、雞排店使用的防油紙袋。模擬調理遷移使用市售大豆沙拉油，該油品係根據大賣場統計銷售最好的油品。

表 24 彙整了本研究不沾鍋採集記錄資料。不沾塗層鍋具係賣場中鍋具類大宗產品，亦是一般家庭中常見的廚房用品，大部分的鍋具產地來自中國，本研究採集之 15 件鍋具即有 9 件來自中國，法國、韓國，越南及台灣各一，鍋具的種類繁多，一般常見材質為鋁、鐵合金，口徑大小普遍為 14-32 cm，價格的範圍更是廣，從不到百元至上千元台幣不等，表 24 標示之價格範圍為 67-890 NT，此範圍為大部分民眾可以接受之範圍。自從發現不沾塗層鍋具之塗層原料 PFOA 可能導致健康危害，不沾塗層鍋具的安全性，尤其在製程方面受到關注，但是許多人並未重視鍋具標示上的使用規定，大部分的鍋具皆有標示使用方法以及清潔方法，包括適用之爐具、鍋鏟材質、清潔劑特性以及避免空燒等注意事項，不正確的使用或清潔會破壞不沾塗層結構，可能加劇 PFOA 釋出情形，增加健康危害之

風險。

表 25 為本研究採集之食品包裝防油紙資料彙整表。防油紙於生活用品之應用廣泛，特別是在飲食方面，本研究尤其關注防油紙袋，台灣小吃文化豐富多元且盛行，許多高溫食品皆使用防油紙包裝售賣，例如鹹酥雞、炸雞排、蔥油餅以及燒烤等熟食。其他產品包括烘培調理紙、紙餐盒、薯條紙袋等皆納入本計畫檢測項目。有標示之防油紙產地皆為台灣製造，材質為紙漿、原木漿等材料，許多產品製造日期標示不清，價格部分自 11-132 NT 不等。採集之物件皆於實驗室量測紙材厚度(mm)，進而估算表面密度(g/cm^2)，以便於後續將 PFOA 特定遷移濃度濃度(SML)單位 ng/g 換算為 ng/cm^2。

本計畫自 99 年 7 月開始採集樣品，包括市場銷售調查、遷移與檢測方法之建立以及方法確認後之實際檢測過程中，前後共計五次之採樣行動，每次行動皆進行事前規畫，確認採樣地點、採集樣品之種類、數量以及估算價格，採樣完畢皆建立採樣紀錄檔案，紀錄登記品名、製造產地、產品編號、使用說明、製造商、進口商及售價等資訊，整理現場拍攝照片，並且上載於 Google 雲端平台，便於日後進行樣品追蹤調查，採樣調查照片如附件 E，檢驗分析照片如附件 F。

3.2.2 不沾鍋檢驗結果與品管查核

本計畫自台中市區各大賣場隨機採集 15 種常見品牌鍋具，進行室溫甲醇遷移、高溫模擬油遷移以及高溫遷移後之室溫甲醇遷移等三種遷移模式，表 26 為本研究不沾鍋之常溫甲醇、高溫油品、高溫油品遷移後再常溫甲醇遷移試驗之原始數據彙整表，列出上機萃出液之濃度(ng/mL)、最後定容體積(10 mL)及總質量(ng)，該表另包括兩筆大豆沙拉油之 PFOA 檢驗結果，均為 ND。PFOA 檢驗及品管查核結果如表 27、表 28 所示，典型之不沾鍋溶出 PFOA 之樣品及標準品圖譜如圖 5、6 所示，表中 ND 值在圖 7、8 中以 1/2ND 值表示，上機液之定量極限為 0.2 ng/mL，若遷移面積為 400 cm^2 時，可換算為該物件之定量極限為 0.005 ng/cm^2 (0.2 ng/mLx10 mL/400 cm^2)。室溫甲醇遷移模式之試驗條件係參考 USEPA (2009)，於保持試驗鍋具之完整性下，進行非破壞性室溫甲醇遷移 24 hr，遷移濃度結果為 ND-0.021 ng/cm^2 (n=15)，上機液定量極限為 0.2 ng/mL，鍋具之定量極限則為 0.004-0.023 ng/cm^2。USEPA (2009)不沾鍋室溫甲醇遷移試驗結果為 ND-0.047 ng/cm^2 (n=14)，偵測極限為 0.01-0.04 ng/cm^2，比較兩研究之遷移條件，

同為室溫下遷移 24hr，溶媒皆為甲醇，但 USEPA 試驗結果最高濃度為本研究最高濃度約 2 倍。另 Begley et al. (2005)進行類似之不沾鍋遷移試驗，試驗結果為 4-75 μg/kg，單位可經過推算之不沾塗層表面積密度 0.01 ng/cm^2 (不沾塗層密度 2.2 g/cm^{3}x厚度 0.005 cm)換算為 0.044-0.82 ng/cm^2，該研究最高濃度結果為本研究最高濃度之 40 倍，究其原因應為 Begley et al. (2005)係將刮取試驗鍋具之不沾塗層成粉末狀，在 50°C 下 24 hr 進行遷移，而本研究係使用原型表面遷移。

本研究繼室溫甲醇遷移後，針對檢出濃度較高之樣品鍋具進行高溫模擬調理遷移，於高溫 125±5°C 下遷移 10 min，溶媒為市售大豆沙拉油，結果未檢出濃度 (n=3)。本遷移模式條件係參考 Bononi and Tateo (2007)，該研究進行鍋具 PFOA 遷移前，先將鍋具作為蕃茄醬製作之容器，以模擬一般家庭使用情形，再將鍋具洗淨後使用橄欖油進行 120-160°C 高溫遷移 10 min，試驗結果為 ND-0.13 ng/dm^2 (ND-0.001 ng/cm^2)。本研究將高溫模擬調理遷移後之鍋具再進行一次室溫甲醇遷移，是為模擬鍋具使用後 PFOA 再遷移情形。結果較室溫甲醇遷移濃度低，甚或未檢出，但較高溫模擬油遷移之濃度高。圖 8 中樣品序號 3、6、7 之濃度為 1/2ND 值。原預期鍋具經過使用會更容易溶出 PFOA，但是結果與預期不符，鍋具中 PFOA 遷移情形與該鍋具遷移(使用)次數的關係值得進一步探討。根據 Begley et al. (2008)研究食品包裝防油紙以各種食品模擬物之高溫模擬遷移結果(見圖 2、圖 3)，單純使用模擬合成油的遷移濃度最低，若在油品中加入離子性或非離子性乳化劑則會使遷移濃度增加，由此推測 Bononi and Tateo (2007)將試驗鍋具先進行番茄醬製作的處理方式可能是檢出濃度的原因，且 Bononi and Tateo (2007)之定量極限(0.05 ng/mL)小於本研究(0.2 ng/mL)，其最大濃度亦低於本研究定量極限，此可能為本研究結果未檢出原因。

3.2.3 防油紙檢驗結果與品管查核

15 件食品包裝防油紙樣品係自台中市區各大賣場、速食店及坊間小吃店隨機取得。本研究之室溫甲醇、高溫模擬油以及高溫模擬後室溫甲醇遷移試驗原始數據彙整如表 29 所示，並列出上機萃出液之濃度(ng/mL)及總質量(ng)。PFOA 檢驗結果與品管執行情形如表 30 及表 31 所示，典型之防油紙溶出 PFOA 之樣品圖譜如圖 9 所示，遷移濃度分佈見圖 10~13，表中 ND 值在圖中以 ND 之 1/2 表示。本研究研擬之防油紙三種遷移模式均採全浸泡式進行，即是將裁取適當大小

(1 g)之防油紙完全浸泡至溶媒中萃取 PFOA。完成遷移試驗所得之濃度單位為 ng/g，以樣品質量(g)與遷移面積(cm^2)之關係式可將單位換算為 ng/cm^2，表中數值為重複樣品之平均值。本研究之室溫甲醇遷移結果 ND-183 ng/g，若除以各物件之表面密度(g/cm^2)，可換算為 ND-0.99 ng/cm^2，比較同樣遷移條件(室溫甲醇 24hr 遷移)之 USEPA (2009)結果 ND-4640 ng/g，可換算為 ND-92.8 ng/cm^2，後者最高濃度約為本研究最高濃度結果之 90 倍。

防油紙的高溫模擬油試驗係參考 Begley et al. (2008)在 100°C 的高溫下，以各種溶媒(水、醋酸、乙醇、奶油及模擬合成油等)進行 15 min 之模擬調理遷移，以單面遷移器進行防油紙遷移，本研究則以全浸泡式進行遷移，結果均未檢出(ND)，若以 1/2ND 計算約為 0.005-0.006 ng/cm^2。Begley et al. (2005, 2008)試驗結果約為 0.12-5.8 ng/cm^2、0.2-1.0 ng/cm^2，但 Begley et al. (2005)係檢測經過 2 min 微波之爆米花紙袋，微波時爐內溫度可高達250°C，可能為導致該高濃度之原因。Begley et al. (2008)結果可參考圖 2 及圖 3，在各種不同溶媒遷移試驗結果比較中，單純使用油品為溶媒有最低之遷移濃度，但若於油品中加入離子性或非離子性乳化劑，則濃度大為增加，國人的烹煮條件常為高溫加油加鹽，建議後續應探討此一重要議題。

本研究防油紙室溫及高溫遷移結果比較情形如表 31，防油紙經過高溫模擬遷移後之再次室溫甲醇遷移，其濃度較直接進行室溫甲醇遷移之濃度低，但高溫遷移濃度之結果均為 ND，重複遷移是否會降低遷移量可進一步探討。

3.3 PFOA 風險評估與安全上限建議

3.3.1 風險評估模式與演算法之建立

表 32 為本研究針對食品接觸物件 PFOA 所建立之健康風險評估數學模式，考量三種暴露路徑：(1) 經食品接觸物件污染(不沾鍋及防油紙)，ADD_c；(2) 經食品及飲用水污染，ADD_{fw}；(3) 經其他路徑(非食品)污染暴露，ADD_{nf}。三路徑加總之均日劑量為 ADD_T，其最大值為每日耐受量(TDI)，本研究採用歐盟建議 TDI 值之 1500 ng/kg-d (EFSA, 2008)，而各路徑之 ADD 與 TDI 之比值定義為暴露比(Exposure Ratio, ER)。

為使不沾鍋及防油紙之 SML 值單位均為 ng/cm^2，根據 USFDA(2007) 食品與物件接觸係數慣用值，假設 10 g 食物會接觸到 1 in^2 的包裝容器表面積，另以

2.54^2 cm^2/in^2 為單位轉換因子，可以推導出下面之公式：

$$SML\ (\frac{ng}{cm^2}) = \frac{TDI\ (ng/kg-d) \times ER_c(\%) \times BW\ (kg)}{IR_f\ (\frac{g}{d}) \times \frac{1}{10}\ (\frac{in^2}{g}) \times 2.54^2\ (\frac{cm^2}{in^2}) \times CF\ (\%)}$$

圖 14 為本研究研擬之 PFOA 健康風險評估之演算法。於保守情境下，藉由最大化 ER_{fw} 及 ER_{nf}，並扣除該二暴露路徑之比例，可推估經食品接觸物件之暴露比例(ER_c)。進一步以 Excel 建立風險評估程式編碼如附件 G，以求得食品接觸物件 PFOA 之 SML 值，不沾鍋及防油紙之 SML 分別表示為 SML_p 及 SML_o，二種物件採用同樣的演算法與單位，以利模式之簡化。

3.3.2 毒理與暴露參數選用及數值模擬

本研究設定三組暴露族群，分別為： 7-18 歲青少年，19-59 歲成年人，以及 60 歲以上年長者。各族群之暴露參數選用說明如下(表 33)：

(1) TDI

表 34 為本研究參考歐盟(EFSA, 2008)所推估 PFOA 之 TDI 值，推估依據：動物試驗之 $BMDL_{10}$ 0.3 mg/kg-d、不確定性因子 UF=200 (亞慢性試驗：2、種間變異：10、種內變異：10)，計算 PFOA 之 TDI 值為 1500 ng/kg-d。

(2) ER_{fw}、ER_{nf}、ER_c 之估算

本研究以保守情境為原則，最大化 ER_{fw} 及 ER_{nf} 暴露比例，表 35 計算最大化之 ER_{fw}、ER_{nf}，設定低、中、高三種暴露情境。各路徑比例估算依據如下：

ER_{fw} 之估算根據：每日攝食量 2 公斤(國民健康局, 2008)、食品 PFOA 濃度為 20 ng/g (Tseng et al., 2006)、每日飲用水攝取量 1.5 L/d (國民健康局, 2008)、飲用水 PFOA 最大容許濃度 10000 ng/L (UKHPA, 2007)(表 36)、以及體重慣用值 60 公斤，估算 ER_f 為 44%，ER_w 為 17%，合計之 ER_{fw} 比例，為 61%。本研究取低、中、高分別為 50%、60%、70%，設定三種風險暴露情境，以推估不沾鍋及防油紙之 SML 值。選用食品 PFOA 之濃度(20 ng/g)，高於其他文獻濃度暴露劑量為 667 ng/kg-d，同時考量飲用水之暴露劑量，為 250 ng/kg-d，故本研究所設定之情境相當保守。

ER_{nf} 之估算根據：國人暴露參數最大呼吸量 20 m^3/d (國民健康局, 2008)、室內總懸浮微粒濃度 300 μg/m^3、空氣中 PFOA 濃度 4000 ng/g，來推估 ER_{nf} 約為

27%。Moriwaki et al. (2003)研究日本室內灰塵，顯示 PFOA 濃度最高者為 3700 ng/g 如圖 15 所示，本研究設定該值為 4000 ng/g，結果 ER_{nf} 為 27%。

ER_c 之估算：扣除上述 ER_{fw} 及 ER_{nf}，可得食品接觸物件佔 TDI 之比例於三種暴露情境下分別為，23%、13%、3%。

(3) 物件材質消費比例係數 CF

CF 之選用係參考 USFDA(2007)食品接觸物質(Food Contact Substances, FCS)指引，不沾鍋為 0.17，防油紙為 0.2。CF 之設定考量三個因素：第一，依據物件製造配方中材質的添加比例，而非材質實際消費比例，例如某食品接觸物件添加聚氯乙烯 (PVC) 為穩定劑，其 CF 採用 0.05，因只有約 50 % 的食品接觸物件含有聚氯乙烯。另一考量因素使用最大產量為依據，每年生產量應等於或低於申報之生產量，若市場容量已超出此申報量，業者須提報申請書。第三、當推出新產品時，將依據其替代產品申報量，或隨著實際使用的情形調整申報量，修正此新產品之物件材質消費比例係數。CF 之推導考量許多因素，包括食品消費種類、食品包裝表面材質、食品包裝單位、容器大小的分配及食品包裝之比例等。USFDA 在計算 FCS 之暴露時，將食品接觸物質 FCS 納入整個市場，考量其之不確定性，包括市場滲透、數據調查之限制。

(4) 食品與物件材質接觸係數慣用值

美國食品藥物管理局(USFDA, 2007)食品與物件材質接觸係數慣用值，假設 10 g 的食品所接觸到包裝容器之表面積為 1 in^2。本研究引用此慣用值為食品與食品接觸物件之接觸係數，將每日攝食量轉換為容器暴露表面積。

(5) 體重(BW)及每日攝食率(IR_f)

國人體重及每日攝食率資料係參考「台灣一般民眾暴露參數彙編」 (國民健康局, 2008)，資料包括各單一年齡 BW 及 IR_f 之樣本數(n)、平均值(M)與標準差(S)。為整合本研究設定之三組暴露族群(7-18 yr、19-59 yr、60+ yr)之數據，使用下列公式計算此三組年齡層 BW 及 IR_f 之平均值(M_p)與標準差(S_p)：

$$M_p = \frac{n_1 \times M_1 + n_2 \times M_2 + \cdots + n_k \times M_k}{n_1 + n_2 + \cdots + n_k}$$

計算 BW 及 IR_f 標準差時，應用 Pooled standard deviation，公式為：

$$S_p = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2 + \cdots + (n_k - 1)S_k^2}{n_1 + n_2 + \cdots + n_k - k}}$$

3.3.3 風險暴露情境設定

表 35 係本研究研擬 PFOA 健康風險評估三暴露情境之設定，根據文獻 Trudel et al.(2008)之 PFOA 研究顯示，北美洲成年人暴露途徑主要以食入為主(>50%)如圖 16。另外，EFSA (2008)指出，PFOA 之暴露在非食品路徑中最大佔 50%，換言之，經食品及飲用水、食品接觸物件暴露之比例大於 50%，其中飲用水部分約 15% (表 37)。因此，本研究參考該文獻之探討以及計算最大化 ER_{fw} 及 ER_{nf} 之暴露比例，求得 ER_{fw} (50%、60%、70%)以及 ER_{nf} (27%)之暴露比，設定其低、中、高三種風險暴露情境。

本研究於推估不沾鍋與防油紙之 PFOA 特定遷移限值(SML_p、SML_o)中，設定三組暴露族群分別為 7-18 歲青少年、19-59 歲成年人、60 歲以上年長者。因年齡不同，於體重(BW)及每日攝食率(IR_f)亦會有所差異。TDI 乃採用歐盟所建議值 1500 ng/kg-day，做為健康風險評估基礎。物件材質消費係數(CF)之選用，則是參考 USFDA(2007)食品接觸物質(Food Contact Substances, FCS)指引，於不沾鍋之 CF 選用 0.17，防油紙之 CF 選用 0.2。

建立三路徑之食品接觸物件 PFOA 健康風險評估之 Excel 模式(附件 G)，代入所設定之各項參數，並應用蒙地卡羅(Monte Carlo Simulation)之方法，使用 Crystal Ball® (Version 7.3, Decisioneering. Inc., Denver, CO, USA)軟體，隨機抽樣數(N)設定為 10,000 次，以機率分佈模式模擬各暴露族群不沾鍋及防油紙之 SML 值。本研究應用機率分佈方式呈現計算結果，故以第 50 百分位數(P50)及第 95 百分位數(P95)建議 SML，在保護 95%的民眾為基礎下，P95 較 P50 更加保守，因此建議以 P95 之 SML 值訂定安全限值。

3.3.4 風險評估結果與安全上限建議

利用本研究建立之三路徑健康風險評估模式與演算法，推估不沾鍋及防油紙各三個族群的特定遷移限值(Specific migration limit, SML)，結果分別如表 38 及表 39 所示，SML 值分別以各族群之 BW 及 IR 機率分配模擬結果之第 50 百分位(P50)及第 95 百分位(P95)表示，比較兩個表，可以看出因為防油紙之物件材質消

費比例係數(CF=0.2)，較不沾鍋 CF(0.17)為高，所以在相同暴露情境下，導致 SML_o 均較 SML_p 低，最易感族群(有最低之 SML 者)均為成年人(19-59 yr)族群，其中最低 SML 者為 ER_{fw} 比例最高者(70%)，防油紙及不沾鍋分別為 1.0 及 2.4 ng/cm^2。我們也將三種族群之模擬結果分別呈現如圖 17~圖 19 所示。各圖中根據食物加水之三種暴露劑量比例(ER_{fw})，顯示最高 ER_{fw} 者，有最低之 FCS 之允許 ER_c 值，而導致最低的 SML 值，各圖中之 SML 上下二條趨勢線分別代表 P50 及 P95 值。

表 40 進一步比較本研究風險評估結果之 SML 值與歐盟及美國的管制限值及評估條件。根據歐盟(EU, 2006) 2006/122/ECOF 指令，對於紡織品及其他塗層之 PFOS，歐盟規定其含量不得高於 0.1 ng/cm^2，因為 PFOA 之 TDI 為 PFOS 之 10 倍，可以推估 PFOA 之管制限值為 1 ng/cm^2，與本研究之評估結果之 SML 相當(same order of magnitude)，但應注意的是本研究係針對食品接觸物件之遷移量，而歐盟係針對所有塗層物件之含量，而非其遷移量。進一步查詢歐盟之 Food Contact Material (FCM)網站資料庫(EUROPA>EC>DG Health and Consumers)，發現 PFOA 是列管於 17 大類 FCM 之第 9 類 Plastics 及第一分類 Additive(9.1)，其目前尚未訂定管制限值，但針對屬性相同之所有化合物(如本研究之所有 PFC)，該資料庫另要求所有 Overall migration limit (OML)之管制限值為 60 mg/kg Food (ppm)，雖然其縮寫使用 SML，但實際上是管制食品中之濃度，故應視為美國之 Dietary concentration limit (DCL)。

進一步查詢美國 FDA 之 Office of Food Additive Safety (OFSA)之 CEDI/ADI 網站資料庫，該資料庫係供食品業者申請食品添加物(FCS)之用，目前共管制 1,267 種 FCS。發現目前已訂有 PFOA 之管制限值，分別為 DCL=0.12 ppb 及 Cumulative estimated daily intake (CEDI)=6 ng/kg-d，假設 IR=3 kg/d，BW=60 kg，將 CEDI 換算為 SML 如下：

$$SML=(6\ ng/kg\text{-}d)(60\ kg)(d/3000\ g)(10\ g/in^2)(in/2.54\ cm)^2$$
$$=0.2\ ng/cm^2$$

在上述假設條件下，顯示經由食物暴露之美國 PFOA 之 SML 管制限值較本研究推估之 1 ng/cm^2 低，本研究係使用國人之 BW 及 IR 以機率分配計算高限 P95 值，而美國係以 BW 及 IR 慣用值進行點推估，若 IR 設定較低及 BW 設定較高，美國之 SML 推估值會更高。

本研究進行不沾鍋及防油紙各15件之PFOA遷移試驗結果已於3.3節討論，不沾鍋室溫甲醇 SML_p=ND-0.021 ng/cm^2 (n=15)，15件中有8件為ND，高溫油品 SML_p 均為 ND(n=3)，高溫油品遷移後再進行室溫甲醇遷移，SML_p=ND-0.0078 ng/cm^2 (n=3)，所有室、高溫不沾鍋之 SML 均低於本研究所建議之安全限值(SML_p=2.4 ng/cm^2)。防油紙室溫甲醇 SML_o=ND-0.99 ng/cm^2 (n=15)，15件中有6件 ND，高溫油品 SML 均為 ND(n=3)，高溫油品遷移後再進行室溫甲醇遷移 SML_o=0.24-0.37 ng/cm^2，所有防油紙室、高溫 SML_o 均低於本研究建議之安全限值(SML_o=1.0 ng/cm^2)。

3.4 研討會與溝通會議

3.4.1 專家學者研討會

本研究於2010年9月15日舉辦「食品器具包裝不沾塗層使用加工助劑全氟辛酸(PFOA)之溶出情形調查及健康風險評估」專家研討會，目的為向各界專家學者請益本研究之研究設計與問題。本研討會呈現三大討論議題：食品接觸物件PFOA遷移之國際管理現況與趨勢、PFOA毒理與食品接觸物件之健康風險評估、PFOS與PFOA之檢測方法開發與品保品管，當天到場來賓共計39人。會議議程(主講人、主持人及與談人)及會議重點討論如附件H所示。

3.4.2 業者溝通會

業者溝通會的目的在於與不沾鍋及食品包裝防油紙業者雙向溝通，讓業者了解PFOA國際議題的現況與趨勢，簡報如**錯誤! 找不到參照來源。**，並提供本研究最新調查分析結果及健康風險評估的SML建議限值。溝通會議定於99年12月1日於中國醫藥大學舉行，由本計畫主持人江舟峰教授擔任主講人，並且由本校公共衛生學院宋鴻樟院長為會議致詞開場，會議第一場為介紹PFOA當前國際管理現況與趨勢，我們榮幸邀請到衛生署食品藥物管理局科技中心高文彥博士擔任該場主持人，第二場係發表本研究PFOA溶出調查結果及健康風險評估，由食品工業發展研究所檢驗中心傅偉光主任擔任主持人，最後在本計畫協同主持人同時亦是本校風險分析中心主任謝顯堂教授的引導下，展開熱烈的綜合討論。當天出席人員達32人，不沾鍋業者邀請到在台灣開業40年製造不沾鍋的勝立公司、達雅公司、紙業大廠合眾公司，在會中熱烈交流意見，會議之重點結論如附件

J。藉由本會議連結政府、學術界及業界，希望能在各界互相協助、互相了解的情況下，達到保護民眾飲食健康的目標。

四、結論與建議

4.1 文獻回顧結論

1. PFOA/PFOS 對人類危害效應尚待確認，但美國(EPA C8)及歐盟(REACH)已訂定排放削減及物質減量、停產或特定工業限制使用時程，乃考量其持續性有機污染物(POP)之長期不易分解之特性。
2. 歐美對 PFOA/PFOS 之 TDI 訂定仍有爭議，EFSA (2008)建議：1500/150 ng/kg-d。
3. PFOA 暴露劑量 2-6 ng/kg-d：食品+飲用水>50%、非食品<50%，HQ = 0.001-0.004。
4. PFOS 暴露劑量 60 - 200 ng/kg-d：食品>98%、非食品<2%，HQ = 0.4 -1.3。
5. FCS 遷移管制：美國 EDI (mg/kg-d) < CEDI，且 DC (mg/kg)<DCL，歐盟與中國 MC (mg/kg)< SML，歐盟另要求同類物質的 MC < OML (=60 mg/kg)，其中 SML之單位為 mg/kg，故應解釋為美國之DCL；若 MC 單位為 mg/dm^2，應將 MC 以 1 kg/6 dm^2 之食品接觸係數轉換為 MC (mg/kg)，再與 SML 比較。
6. Begley et al. (2008)進行高溫防油紙遷移試驗，發現在模擬油下不易溶出 PFOA，但加上離子鹽或乳化劑則會大幅提高遷移量。

4.2 遷移試驗及風險評估結論

1. 本研究建立 PFOA 室溫及高溫遷移試驗方法及 HPLC/MS/MS 之定量分析方法，可符合 USFDA (2007)品管基準：全程 RCSS 之 Recovery 為 60-110%及 RPD<20%；上機液 LOQ=0.2 ng/mL (0.004-0.068 ng/cm^2)。
2. 室溫甲醇遷移試驗結果：不沾鍋 ND-0.021 ng/cm^2 (n=15)，防油紙 ND-0.99 ng/cm^2 (n=15)。
3. 高溫模擬油試驗結果：不沾鍋 ND (n=3)，防油紙 ND (n=3)，顯示即使在高溫(100-125℃)，PFOA 不易於模擬大豆沙拉油中溶出。
4. 高溫模擬油遷移後再進行室溫甲醇遷移試驗結果：不沾鍋 ND-0.0078 ng/cm^2 (n=3)，防油紙 0.24-0.37 ng/cm^2 (n=3)，說明再溶出之可能。
5. 本研究建立一個三暴露路徑之風險評估模式，將食品+飲用水(ER_{fw})以及非食品(ER_{nf})暴露路徑，以保守情境估算二者佔總 TDI 之最大比例：ER_{nf} 為

27%；ER_{fw}分別為 50%、60%、70%。

6. 因 CF 參數之影響，三組暴露族群之不沾鍋與防油紙之 SML 比較，防油紙皆低於不沾鍋(防油紙 CF 為 0.2，不沾鍋 CF 為 0.17)。
7. 於保守情境下，三組暴露族群中，由於 BW 與 IR 的差異，7-18 歲青少年有最低的第 50 百分位數(P50)SML；19-59 歲成年人第 95 百分位數(P95)SML 低於青少年及年長者。
8. 建議我國不沾鍋及防油紙之 PFOA 特定遷移管制限值採用 P95 之 SML_p=2.4 ng/cm^2，SML_o=1.0 ng/cm^2。本研究所有常溫甲醇及高溫模擬試驗結果均未超過此一限值；唯防油紙之最大遷移濃度已接近本研究推估建議之 SML。
9. 推估歐盟(EU, 2006)之塗層物件 PFOA 管制限值為 1 ng/cm^2，美國(USFDA, 2007)之食品 PFOA 暴露管制限值為 0.2 ng/cm^2，本研究模擬結果與歐盟推估值相當。

4.3 建議

1. 我國 FCS 管制：較偏向歐盟方法，建議檢討相關辦法，釐清：遷移濃度計算方法、溶媒體積、暴露面積、管制標準等議題。
2. 一般認為食品接觸物件 PFOA 的風險甚低，但在國人特殊高溫烹煮條件下(油+離子/非離子性物質)，是否會成為重要暴露來源，應進一步釐清。
3. 建議針對 PFOS，調查肉類、乳製品及水產食物之 PFOS 含量，並進行健康風險評估。
4. 建議逐年調查國人血液中 PFOA 及 PFOS 之濃度，了解其濃度變化趨勢。
5. 參考歐盟之管制指令(2006/122/ECOF)，建議我國食品接觸物件 PFOS 之 SML 管制限值為 0.1 ng/cm^2。

五、經費使用狀況

99 年度經費支用一覽表

執行單位：中國醫藥大學健康風險管理學系

計畫編號：99TFDA-TC-102

計畫名稱：食品器具包裝不沾塗層鍋具使用加工助劑全氟辛酸之溶出情形調查及健康風險評估

執行期限：中華民國 99 年 6 月 15 日起至 99 年 12 月 31 日止

項目		1.人事費	2.業務費		3.管理費	備註
核定金額(元)		615,050 元	1,216,600 元		95,950 元	人事費 36,822 元流用至業務費
細項		薪資	材料費	其他		
支用金額(元)	第 1 個月	35,600	-	-		
	第 2 個月	71,200	96,672	19,896		
	第 3 個月	71,200	295,784	58,092		
	第 4 個月	71,200	284,148	75,441		
	第 5 個月	71,200	274,960	43,982		
	第 6 個月	71,200	48,436	51,011		
	第 7 個月	71,200		5,000	95,950	
	第 8 個月					
	第 9 個月					
	第 10 個月					
	第 11 個月					
	第 12 個月					
	計	462,800	1,000,000	253,422	95,950	1,812,172

統計至 12/10 日止

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七、附表

表 1　美國 FCS 申請應送審資料(USFDA, 2007)

項次	應繳交資料
1	食品接觸物件中最高 FCS 使用濃度(Max use level in article)
2	該 FCS 各種可能應用(Range of possible uses)，如 Films, molded articles, coating 等
3	最大厚度或最大單位面積重
4	食品型態(Food types)
5	最大暴露溫度與時間
6	FCS 之穩定性(Stability)

表 2　美國 FCS 申請之食物模擬物選用原則(USFDA, 2007)

	Food-Type as defined in 21 CFR 176.170[c] Table 1	**Recommended Simulant**
1	Aqueous & Acidic Foods (Food Types I, II, IVB, VIB, and VIIB)	10% Ethanol[a]
2	Low- and High-alcoholic Foods (Food Types VIA, VIC)	10 or 50% Ethanol[b]
3	Fatty Foods (Food Types III, IVA, V, VIIA, IX).	Food oil (*e.g.*, corn oil), HB307, Miglyol 812, or others[c]

[a] for exceptions, see main text.
[b] actual ethanol concentration may be substituted.
[c] HB307 is a mixture of synthetic triglycerides, primarily C_{10}, C_{12}, and C_{14}. Miglyol 812 is derived from coconut oil.

表 3　美國 FCS 申請之食品種類分配係數 f_T (USFDA, 2007)

	Package Category	Food-Type Distribution (f_T)			
		Aqueous[a]	Acidic[a]	Alcoholic	Fatty
A. General	Glass	0.08	0.36	0.47	0.09
	Metal- Polymer coated	0.16	0.35	0.40	0.09
	Metal- Uncoated	0.54	0.25	0.01[b]	0.20
	Paper- Polymer coated	0.55	0.04	0.01[b]	0.40
	Paper- Uncoated and clay-coated	0.57	0.01[b]	0.01[b]	0.41
	Polymer	0.49	0.16	0.01[b]	0.34
B. Polymer	Polyolefins	0.67	0.01[b]	0.01[b]	0.31
	Polystyrene	0.67	0.01[b]	0.01[b]	0.31
	-impact	0.85	0.01[b]	0.04	0.10
	-nonimpact	0.51	0.01	0.01	0.47
	Acrylics, phenolics, etc.	0.17	0.40	0.31	0.12
	PVC	0.01[b]	0.23	0.27	0.49
	Polyacrylonitrile, ionomers, PVDC	0.01[b]	0.01[b]	0.01[b]	0.97
	Polycarbonates	0.97	0.01[b]	0.01[b]	0.01[b]
	Polyesters	0.01[b]	0.97	0.01[b]	0.01[b]
	Polyamides (nylons)	0.10	0.10	0.05	0.75
	EVA	0.30	0.28	0.28	0.14
	Wax	0.47	0.01[b]	0.01[b]	0.51
	Cellophane	0.05	0.01[b]	0.01[b]	0.93

[a] For 10% ethanol as the food simulant for aqueous and acidic foods, the food-type distribution factors should be summed.

[b] 1% or less

表 4　美國 FCS 申請之物件材質消費係數 CF (USFDA, 2007)

	Package Category	CF	Package Category	CF
A. General	Glass	0.1	Adhesives	0.14
	Metal- Polymer coated	0.17	Retort pouch	0.0004
	Metal- Uncoated	0.03	Microwave susceptor	0.001
	Paper- Polymer coated	0.2	All Polymers[a]	0.8
	Paper- Uncoated and clay-coated	0.1	Polymer	0.4
B. Polymer	Polyolefins	0.35[b]	PVC	0.1
	-LDPE	0.12	-rigid/semirigid	0.05
	-LLDPE	0.06	-plasticized	0.05
	-HDPE	0.13	PET[c,d]	0.16
	-PP	0.04	Other Polyesters	0.05
	Polystyrene	0.14	Nylon	0.02
	EVA	0.02	Acrylics, phenolics, etc.	0.15
	Cellophane	0.01	All Others[e]	0.05

[a] Originates from adding CFs for metal-polymer coated, paper-polymer coated, and polymer (0.17 + 0.2 + 0.4 = 0.8).

[b] Polyolefin films, 0.17 (HDPE films, 0.006; LDPE films, 0.065; LLDPE films, 0.060; and PP films, 0.037).

[c] PET-coated board, 0.013; thermoformed PET, 0.0071; PET carbonated soft drink bottles, 0.082; custom PET, 0.056; crystalline PET, 0.0023; PET films, 0.03.

[d] A CF of 0.05 is used for recycled PET applications (see the document entitled "Points to Consider for the Use of Recycled Plastics in Food Packaging: Chemistry Considerations").

[e] As discussed in the text, a minimum CF of 0.05 will be used initially for all exposure estimates.

表 5　美國食品安全及應用營養中心(USFDA, 2007)之遷移試驗結果計算例

1. 若遷移試驗結果，遷移濃度 MC=1 mg/kg

2. 若該平板物件單位重量，Unit weight=50 mg/in^2

3. $MC=(1\frac{mg}{kg})(50\frac{mg}{in^2})(\frac{1\,kg}{10^6\,mg})=5\times10^{-5}$ mg/in^2

4. 假設單位面積盛裝食品慣用值為 10 g food/in^2

5. 若該平板物件為 Metal-polymer coated，溶媒為 Alcoholic，查表 3，$f_T=0.40$

6. 食物中之濃度

$$DC=(5\times10^{-5}\ \frac{mg}{in^2})(\frac{in^2}{10\,g})(\frac{1\,g}{10^3\,mg})(0.40)=2\times10^{-9}\ \frac{mg}{mg}=2\ ppb=2\ \frac{mg}{kg}$$

7. 假設每人每日攝食量 3 kg/head-day，平均體重 60 kg

8. 考量表 4 之物件材質消費係數 CF=0.17，計算每日攝食量

$$EDI=(\frac{2\,mg}{kg})(\frac{3\,kg}{head-d})(\frac{head}{60\,kg-bw})(0.17)=0.017\ \frac{mg}{kgbw-d}$$

表 6　中國法規遷移濃度單位換算之整理(2003 版本)

食品容器	定義	結果計算	補充
空心製品	大　容量大於等於 1.1L，小於 3L 者； 小　容量小於 1.1L 者。	以測定所得毫克每升（mg/L）表示。	
扁平製品	置於水平位置時，從其內部最低至盛滿液體時的溢流面的深度小於或等於 25 mm 的製品，如盅、碟。	● 遷移濃度單位為 mg/L 時，代入公式一： $a=\frac{cV}{2S}$ a：遷移濃度(mg/L)； c：溶出濃度(mg/L)； V：浸泡液體積(mL)； S：扁平製品參考面積(cm^2)； 2：每平方公分面積所需的溶劑毫升數。 ● 遷移濃度單位為 mg/dm^2 時，代入公式二： $a_0=\frac{cV}{A}$ a_0：遷移濃度(mg/dm^2)； c：溶出濃度(mg/L)； V：浸泡液體積(L)； A：樣品參考面積(dm^2)。	● 浸泡液體積為 2 mL 時，則測得之溶出濃度即樣品遷移濃度(mg/L)。 ● 浸泡液多於或少於每平方公分 2 mL，則以測得之溶出濃度(c)按公式一計算。
貯存器	容量大於等於 3L 的製品。		

表 7　文獻中不沾塗層鍋具及防油紙模擬調理遷移試驗條件比較

	文獻出處	模擬調理條件
1	歐盟指引 (EU, 2004)	實際使用最嚴格烹調條件
2	USFDA (2007)	實際使用最嚴格烹調條件，考量 Simulant type 分配係數 (f_T)，使用 4 種食品模擬物
3	Begley et al. (2005)	1. 不沾鍋及防油紙，粉末浸泡，50°C，24 hr 2. Microwaveble popcorn
4	Begley et al. (2008)	防油紙 1. 各類 Simulant：Water, Vinegar, 10-30% EOH, Butter, Miglyol, Oil＋ionic, Oil＋nonionic 2. 100°C, 15 min, Single-sided Migration cell
5	Bononi and Tateo (2007)	不沾鍋，先烹調 Tomato sauce 1. Oliver oil, 20 mL, 120-160°C, 10 mL 2. Potato stick, 50 mL preheated oliver oil, 10 min
6	USEPA (2009)	不沾鍋使用盛裝法，防油紙使用全浸泡，甲醇室溫暴露 24 hrs，適時攪拌

表 8　文獻中不同物件 PFOA 檢測方法之比較

文獻出處	樣品類別	儀器	PFOA 鑑定方式	溶媒	LOQ[a]	回收率
Powley et al., 2005 (Dupont)	鍋具	LC/MS/MS	以母離子 413 子離子 369 之一組離子對及相同滯留時間	高溫，水	0.05 ng/mL (0.06-0.1 ng/cm^2)	98±14%
Begley et al., 2005 (USFDA)	防油紙 鍋具	LC/MS/MS	以母離子 413 子離子 369 之一組離子對及相同滯留時間	室溫，乙醇/水 50°C，甲醇	NA[b]	防油紙 PFOA-^{13}C 60-75% 鍋具 PFOA-^{13}C >90%
Stadalius et al., 2006	防油紙 紡織	LC/MS/MS	以母離子 413 子離子 369 之一組離子對及相同滯留時間	室溫，甲醇	1 ng/mL (5 ng/g)	防油紙 110±7.6% (n=55) 紡織 114±4.9% (n=54)
Bononi and Tateo, 2007	鍋具	LC/MS/MS	以母離子 413 子離子 369 及 168 之兩組離子對及相同滯留時間	高溫， 橄欖油/甲醇	0.05 ng/mL	93-95%
Liu et al., 2009 (USEPA)	膠帶 床墊保護墊 衣料 地毯 薄膜 鍋具	LC/MS/MS	以母離子 413 子離子 369 之一組離子對及相同滯留時間	室溫，甲醇	0.3 ng/mL	RCSS 回收率要求 100±20%

[a] 定量極限(Limit of quantification)　[b] Not available

表 9　文獻研究中不沾鍋及防油紙 PFOA 各種遷移試驗條件與遷移濃度

遷移物件	文獻出處	溶媒	遷移試驗條件	遷移濃度(原始值)	遷移濃度(換算值)[f]
防油紙	Begley et al., 2005	模擬合成油(爆米花)	微波超過 200 °C，2 min	6-290 μg/kg	0.12-5.8 ng/cm^2
	Begley et al., 2008	水	100 °C，15 min	0.02-1.9 mg/kg	0.4-38 ng/cm^2
		醋酸		0.01-1.1 mg/kg	0.2-22 ng/cm^2
		10-30%乙醇		0.01-2 mg/kg	0.2-40 ng/cm^2
		奶油		0.44-3.3 mg/kg	8.8-66 ng/cm^2
		模擬合成油		0.01-0.05 mg/kg	0.2-1 ng/cm^2
	U.S EPA, 2009[a]	甲醇	室溫，24 hr	ND- 4640 ng/g	ND-92.8 ng/cm^2
不沾鍋	Powley et al., 2005	水	100 °C，30 min	ND[c]	
		乙醇/水[b]	125 °C，1000 psi，10 min	ND[d]	
	Begley et al., 2005[e]	甲醇(塗層粉末)	50 °C，24 hr	4-75 μg/kg	0.04-0.8 ng/cm^2
	Bononi and Tateo, 2007	橄欖油	120-160 °C，10 min	<0.01-0.13 ng/dm^2	<0.01-0.01 ng/cm^2
		橄欖油預熱後加入馬鈴薯條	熱炒 10 min	<0.01-0.25 ng/dm^2	<0.01-0.03 ng/cm^2
	U.S EPA, 2009	甲醇	室溫，24 hr	ND-0.05 ng/cm^2	

[a] 防油紙剪成片狀約 1 g 後，採全浸泡式遷移

[b] 乙醇/水的調配比例係模擬食物特性，分為 1：9(水、酸性)和 19：1(油脂類)

[c] Not detected (LOD＝10 ppt)

[d] Not detected (LOD=100 ng/cm^2)

[e] 不沾鍋空燒後取其不沾塗層，磨成粉狀

[f] 換算值係原始值乘以本研究估算之不沾塗層表面積密度 0.01 g/cm^2 或防油紙表面積密度 0.02 g/cm^2

表 10　加拿大 1999-2004TDS 食物樣品測得之 PFOA 及 PFOS 濃度(ng/g，d.w.) (Tittlemier et al., 2007)

Composite	Year	PFOA	PFOS
Beef steak	2004	<0.5	2.7
Roast beef	2004	2.6	<0.6
Ground beef	2004	<0.4	2.1
Luncheon meats, cold cuts	2004	<0.4	0.5[a]
Fish, marine	2004	<0.5	2.6
Fish, freshwater	2004	<0.5	2.0
Fish, freshwater	1998	<2	1.5, 1.3[b]
Pizza	1998	0.74	<1
Microwave popcorn	1999	3.6	0.98

[a] The concentration measured was above the LOD but below the LOQ.
[b] Results from analysis of an analogous sample that was stored in glass.

表 11　微波後五種品牌爆米花中全氟化物(PFC)濃度(ng/g，d.w.) (Begley et al., 2008)

微波爆米花種類	濃度 (ng/g)
A	2300
B	1400
C	3900
D	1400
E	1500
94% fat-free	<500

表 12　各類水產食品中 PFOA 濃度(ng/g，d.w.)(EFSA, 2008)

	PFOA (ng/g)	Reference
Europe		
Fish (liver)	0.89-53.0	Kallenborn et al., 2004 Van Leeuwen et al., 2006
Fish, crustacean& mollusk species	1.1-3.2	Van Leeuwen et al., 2006
Fish	0.10-0.39	Berger et al., 2007
Asia		
Fish, crustacean& mollusk species	0.204-1.67	Gulkowska et al., 2006 So et al., 2006
Tilapia fish & oysters	18.6-22.9	Tseng et al., 2006
North America		
Arctic cod, clams& shrimps	ND	Tomy et al., 2004
Smelt & trout (muscle)	0.76-3.1	Martin et al., 2004a Furdui et al., 2005
Fish (liver)	0.16-5.3	Martin et al., 2004b Tomy et al., 2004 Tittlemier et al., 2005
Fish (muscle)	ND	Kannan et al., 2005

表 13　各類水產食品中 PFOS 濃度(ng/g，d.w.)(EFSA, 2008)

	PFOS (ng/g)	Reference
Europe		
Mediterranean fish (livers)	<1-87	Kannan et al., 2002
Shrimps	19-520	Hoff et al., 2003
Crab	93-292	Van de Vijver et al., 2003
Fillet of flounder	93-230	Van Leeuwen et al., 2006
Asia		
Crustaceans and molluscs	0.114-0.586	Nakata et al.,2006 So et al., 2006
Fish, crustaceans and molluscs	0.33-2.93	Gulkowska et al., 2006 (China)
Tilapia fish & oysters	35.8-47.2	Tseng et al., 2006 (Taiwan)
Crap & catfish (livers)	<0.3-41.6	Greenpeace, 2010 (China)
North America		
Oysters	<9.9-99.5	Kannan et al., 2002
Arctic cod, clams& shrimps	0.08-4.7	Tomy et al., 2004

表 14　兩種水體中 PFOA 及 PFOS 濃度(EFSA, 2008)

Country	PFOA (ng/L)	PFOS (ng/L)	Reference
Sea water			
Japan, Tokyo Bay	--	8-59	Taniyasu et al., 2003
Brazil, Guanabara Bay	0.7-3.25	0.4-0.92	Quinete et al., 2009
Drinking water			
Germany	500-640	--	Holzer et al., 2008
Brazil	0.35-2.82	0.58-6.70	Quinete et al., 2009
Japan	2.3-84	0.16-22	Takagi et al., 2008
Italy	1.0-2.9	6.2-9.7	Loos et al., 2007
Spain	0.32-6.28	0.39-0.87	Ericson et al., 2008
China	<0.1-45.9	<0.1-14.8	Jin et al., 2009

表 15　台灣及一些國家河川 PFOA/PFOS 濃度

Region	Occurrence area	Impact	PFOA (ng/L)	PFOS (ng/L)	Reference
Taiwan	Xiaoli	1	17.3	82	Lin et al., 2009
Taiwan	Touchien	1	10.9	48.9	Lin et al., 2009
Taiwan	Keya	1	310	5440	Lin et al., 2009
Japan	Tsurumi River	STP	13.4-15.9	179.6-179.9	Zushi et al., 2008
China	Yangtze River	1, U, P	2.0-260	<0.01-14	So et al., 2007
China	Pearl River Guangzhou	1, U, P	0.85-13	0.9-99	So et al., 2007
Germany	Rivers	WWTP	10-23	1.7-16	Becker et al., 2008
N-Italy	Po River	1	2-337	2-12	Loos et al., 2008
	T'anaro River		1270	2	
U.S.A	Tannessee River	2	Nd-598	16.8-144	Hansen et al., 2002

1, industrial discharge; STP, sewage treatment plant; U, urban discharge; WWTP, wastewater plant; P, populated area.; 2, Highest by fluorochemical manufacturing facility

表 16　河川和潮灘之沉積底泥濃度資料

國家	檢測樣品	PFOA (ng/g)	PFOS(ng/g)	文獻出處
美國	河川、海灣淤泥	ND-0.63	ND-3.76	Higgins et al., 2005
	WWTP 汙泥	ND-29.4	14.4-2610	
日本	海口灘塗淤泥	0.84-1.1	0.09-0.14	Nakata et al., 2006
德國	WWTP 上游河川底泥	<0.03-0.05	<0.05-0.29	Becker et al., 2008
	WWTP 下游河川底泥	<0.03-0.18	0.07-0.54	

WWTP, Wastewater Treatment Plant

表 17　住家室內灰塵中 PFOA 及 PFOS 濃度(單位 ng/g)

國家	樣品數	PFOA (mean)	PFOS (mean)	文獻出處
日本	16	69-3700 (380)	11-2500 (200)	Moriwaki et al., 2003
加拿大	67	<2.3-1234 (106)	<4.6-5065 (444)	Kubwabo et al., 2005

表 18　日常用品中 PFOA 濃度(ng/g) (USEPA , 2009)

Category name	**(ng/g)**
Dental floss and plaque	5.48-96.7
Miscellaneous [a]	ND-125
Treated apparel	5.44-161
Membranes for apparel	9.15-163
Treated-non-woven medical garment	46.2-369
Treated home textile and upholstery	0.61-438
Pre-treated carpeting	ND-462
Household carpet/fabric liquids and foams	ND-1180
Thread seal tapes and pastes	ND-3490
Treated floor waxes and stone/woods sealant	7.5-3720
Commercial carpet-care liquids	19.1-6750

[a] Includes four car-care products, two boat-care products, one deck cheaner, and sack for outdoor use.

表 19　本研究研擬之 PFOA 檢測方法所使用之 LC/MS/MS 之儀器操作條件

HPLC[a]

層析管柱　型號：Agilent ZORBAX Eclipse XDB-C18
尺寸：2.1x50mm 3.5μm

保護管柱　型號：Agilent ZORBAX Eclipse XDB-C8
尺寸：2.1x12.5mm 5μm

自動進樣器　注射量：10 μL

管柱控溫器　管柱控溫：40 °C

移動相幫浦　動相梯度條件：

層析時間(min)	移動相百分比	
	移動相 A (%)	移動相 B (%)
-3.0 (管柱平衡)	80	20
0 (注射)	80	20
0.5	50	50
5.5	5	95
8.0	5	95
8.1	80	20
10.0	80	20

動相流速：0.3 mL/min

層析移動相 A：試劑水含 2mM 醋酸銨

層析移動相 B：甲醇

ESI-MS/MS[b]

電噴灑離子源

Collision gas（arbitrary unit (setting)）	5
Curtain gas （arbitrary unit (setting)）	10
Ion source gas 1 （arbitrary unit (setting)）	45
Ion source gas 2 （arbitrary unit (setting)）	60
IonSpray voltage (V)	-4500
Temperature (°C)	500

串聯式質譜儀　監測離子對：

Analyte	Precursor ion (m/z)	Product ion (m/z)	DP (V)	CE (eV)
PFOA	413	369*	-45	-14
		169**	-45	-23
PFOA -$^{13}C_4$	417	372	-45	-14
PFDA -$^{13}C_2$	515	470	-55	-14

DP：Declustering Potential

CE：Collision Energy

* PFOA 定量離子

** PFOA 定性離子

[a] 高效能液相層析儀(HPLC)：廠牌 Agilent，型號 1200

[b] 電噴灑式串聯質譜儀(ESI-MS/MS)：廠牌 AB，型號 API 5000

表 20　本研究研擬之食品接觸物件溶出 PFOA 檢測方法之品質管制要求

	品質管制項目	管制範圍	文獻出處
1	檢量線線性	線性 r > 0.995	TFDA, 2010
2	回收查核擬似標準品(RCSS)	回收率 60-110%	USFDA, 2007
3	檢量線確認	相對差異百分比±15%	USEPA, 2009
4	檢量線查核	相對差異百分比±15%	USEPA, 2009
5	重複樣品	相對差異百分比 <20%	USFDA, 2007
6	方法空白樣品	<1/2 檢量線最低濃度	TFDA, 2010
7	查核標準品	回收率 60-110%	TFDA, 2010
8	質譜鑑別離子比	(參考註一)	EU, 2002

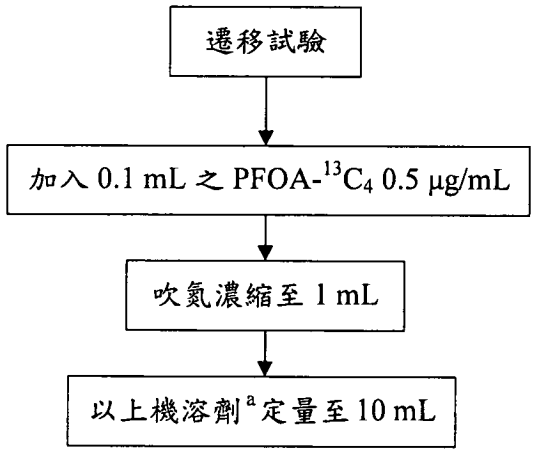
註一：質譜鑑別標準以鑑別離子層析峰面積/定量離子層析峰面積[a]

[a]

離子比(%)	管制範(%)
>50	±20
>20~50	±25
>10~20	±30
≦10	±50

表 21　本研究研擬 PFOA 分析方法之回收查核擬似標準品(RCSS)添加量之計算例

樣品之前處理流程：



回收率 R %計算如下：

$$R\% = \frac{A}{S} \times 100\%$$

A＝RCSS之測定濃度
S＝RCSS之添加濃度

例：若 RCSS 測定濃度為：4.9 ng/mL
RCSS 添加濃度為：5 ng/mL，0.5 μg/mL(0.1mL/10mL)=5 ng/mL
R=(4.9 ng/mL)/(5 ng/mL)=98%

[a] 甲醇:2mM 醋酸銨(1:5, v/v)

表 22　本研究研擬之 PFOA 分析方法之各種 PFOA 樣品上機施打順序

分析類別	樣品上機順序	樣品類型[ab]	備註
檢量線	1~5	5 點檢量線	建立檢測濃度範圍
	6	檢量線確認	以不同於檢量線製作來源之標準品確認檢量線之適用性
批次樣品	1	檢量線查核	確認查核分析過程中使用的檢量線準確性，決定此批次實驗是否須重新製作檢量線
	2	方法空白樣品	監測分析過程中是否遭受污染
	3	查核標準品	確認分析結果之準確度或品質
	4~13	樣品及重複樣品 1~10	分析樣品及重複樣品
	14	檢量線查核	確認分析前後之品質

[a]所有樣品於前處理後，皆添加回收查核擬似標準品(RCSS)

[b]所有樣品皆於上機前添加內標準品(IS)

表 23　本研究消除 PFOA 背景干擾之各項措施

	原儀器使用之管件材質及溶劑	更換非 PTFE 管件材質及溶劑
1	PTFE 材質之移動相溶劑抽取管	改為 1/8"不鏽鋼管
2	PTFE 材質之移動相溶劑瓶內過濾器接頭	改為以 0.2 um 之 Nylon 膜與先過濾動相溶劑
3	抽取管連接線上溶劑除氣裝置(Degaser)之膜片	不連接(Bypass)該除氣設備，事先以 Supersonic 去除氣泡
4	PTFE 材質之動相 Pump seal	改為 PE 材質之 Pump seal
5	玻璃材質樣品瓶 (吸附 PFC)	改為 PP 材質之樣品瓶
6	PTFE 材質樣品瓶蓋	改為 PP 材質之樣品瓶蓋
7	動相溶劑分注器 PTFE 管線	直接由溶劑儲存瓶倒出製備動相溶劑甲醇
8	動相試劑水 (Mili-pore)	去離子水經 C18 SPE 淨化
9	玻璃定量瓶、儲存瓶、離心管	改用 PP 材質

表 24　本研究不沾鍋具採樣紀錄彙整表

	採樣賣場	樣品編號	產地	鍋身材質	標稱直徑(cm)	價格(NT.)	製造日期	產品標示
1	大潤發	O990812A	台灣	鐵	14	67	98/12	將鍋子洗淨，用紙巾拭乾，少許食用油預熱，小火料理
2		O990812C	越南	鋁合金	26	309	99	第一次使用前，裝八分滿的水煮沸、倒掉擦乾，以紙巾沾少量食用油擦拭鍋具。待鍋具冷卻後，以海綿、中性清潔劑清洗。使用不沾鍋專用匙、木匙、木鏟
3	台糖	O990823K	中國	高級合金	28	299	99/04/25	第一次使用先將鍋具洗淨，溫火烘乾，倒入些許油均勻塗抹預熱。請勿空燒。使用木製、竹製或耐熱橡膠鍋鏟。勿使用鐵刷、強力菜瓜布或去汙粉清洗。
4		O990823L	--	--	30	219	99/06	使用木製或耐熱鍋鏟，勿用尖銳金屬用具。勿用大火烹調。使用柔軟清潔布，勿用鋼絲球等尖銳物品清洗。
5		O990823M	中國	鋁合金	32	498	97/12	使用以小火溫鍋，避免大火及空燒。以海綿清洗，勿用硬質菜瓜布或鋼絲球。使用木質或無毒性樹脂鍋鏟，勿用金屬鍋鏟。
6		O990823N	中國	鋁合金	30	199	99/04	第一次使用前，先用豬油加熱或倒入熱牛奶煮沸抹拭鍋面，效果更好。
7		O990823O	中國	合金	26	149	--	使用前確認把手鍋具符合規格，以專用清潔劑清洗、拭乾。燒焦黏著時用熱水浸泡，勿用刀子刮除。
8		O991117H	韓國	--	26	890	--	升溫快，勿用大火調理，加入少許油約 30 秒即達燃火點。
9	愛買	O991117A	法國	鋁合金	30	699	--	第一次使用前，裝八分滿的水煮沸、倒掉擦乾，以紙巾沾少量食用油將擦拭鍋具。使用木鏟、筷子或不沾鍋專用塑膠產，勿用金屬鐵鏟。以中小火烹調即可，避免空燒。用海綿、軟布及一般洗碗精清潔即可，勿用菜瓜布或金屬絲
10		O991117B	中國	鋁合金	30	599	98	勿空燒，勿於鍋具中注滿水或油使用。燒焦黏著時浸泡熱水，勿用刀子刮除。

表 24　本研究不沾鍋具採樣紀錄彙整表(續)

	採樣賣場	樣品編號	產地	鍋身材質	標稱直徑 (cm)	價　格 (NT.)	製造日期	產品標示
11	愛買	O991117C	--	輕合金	32	240	99/05/07	以中小火烹調，適用木產、竹鏟、尼龍鏟。使用後以棉質清洗器清潔。
12		O991117D	中國	複合金	30	699	98/09/07	新鍋使用前先用清潔劑清洗乾淨後抹上食用油。烹調時使用少量油及中小火。請勿空燒。連續使用溫度勿超過 288°C。勿使用金屬或銳利器具炒拌。使用後勿以冷水立即清洗，勿以粗糙菜瓜布或鐵絲絨大力擦洗。
13		O991117E	中國	鋁板	30	349	--	新鍋使用前，以濕的軟性清洗抹布沾沙拉脫等中性清洗劑將鍋子內外全部清洗乾淨。在鍋內裝入清水八分滿，至於瓦斯爐或電爐煮沸 3~5 分鐘，再以清水沖洗乾淨即可使用。不適用金屬鍋鏟。請勿空燒。
14		O991117F	中國	鋁合金	28	599	97	使用中請勿碰觸鍋具，油勿加入鍋具過半。油溫勿超過 200°C。醋、酸類物質可能導致鍋具生鏽。
15		O991117G	中國	鋁合金	28	399		新鍋使用前用少許清潔劑清潔，抹上食用油。選用木鏟。中小火烹調，避免乾燒。使用後勿馬上注入冷水清洗。

表 25　本研究食品包裝防油紙採樣紀錄彙整表

	地點	樣品編號	產地	材質	厚度(mm)	密度(g/cm^2)	製造日期	價格(NT.)
1	大潤發	O990804F	台灣	--	0.06	0.005	--	38
2		O990804G	台灣	--	0.04	0.004	--	32
3		O990804H	台灣	--	0.04	0.004	--	29
4		O990804K	台灣	--	0.04	0.004	--	85
5		O990810A	台灣	紙漿	0.48	0.035	98/08/05	19
6		O990810B	台灣	長織淋膜單面 PE 專用紙	0.48	0.036	98/09/05	11
7		O990810C	台灣	原木漿	0.04	0.004	96/06	132
8	早餐店	O990810E	--	--	0.07	0.005	--	--
9	雞排店	O990810F	台灣	--	0.04	0.006	--	--
10		O990823A	--	--	0.07	0.005	--	--
11		O990823B	--	--	0.07	0.005	--	--
12		O990823C	--	--	0.07	0.005	--	--
13		O990823D	--	--	0.07	0.005	--	--
14		O990823E	--	--	0.07	0.005	--	--
15	早餐店	O990823F	--	--	0.06	0.005	--	--

表 26　本研究不沾鍋遷移試驗原始數據彙整表

序號	樣品編號[a]	直徑(cm)	萃出濃度 (ng/mL)	定容體積 (mL)	PFOA 遷移量 (ng)
室溫甲醇					
1	O990812A	10.5	ND	10	ND
2	O990812C	19.3	0.25	10	2.5
3	O990823K	22.5	0.46	10	4.6
4	O990823L	22.2	0.21	10	2.1
5	O990823M	22	0.36	10	3.6
6	O990823N	22.1	0.72	10	7.2
7	O990823O	18.8	0.58	10	5.8
8	O991117H	18.7	ND	10	ND
9	O991117H-SP	18.7	ND	10	ND
10	O991117B	24.8	0.04	10	0.4
11	O991117B-SP	24.8	0.04	10	0.4
12	O991117C	24.7	ND	10	ND
13	O991117C-SP	24.7	ND	10	ND
14	O991117D	24	ND	10	ND
15	O991117D-SP	24	ND	10	ND
16	O991117E	20.5	0.04	10	0.4
17	O991117E-SP	20.5	0.04	10	0.4
18	O991117F	14.7	0.04	10	0.4
19	O991117F-SP	14.7	0.04	10	0.4
20	O991117G	20.5	ND	10	ND
21	O991117G-SP	20.5	ND	10	ND
22	O991117I	18.5	0.21	10	2.1
23	O991117I-SP	18.5	0.23	10	2.3
24	O991123S	19.3	<0	10	ND
25	O991123S-SP	19.3	<0	10	ND
26	O991129D	17.2	0.01	10	0.1
27	O991129D-SP	17.2	0.01	10	0.1
28	O991129E	20.7	ND	10	ND
29	O991129E-SP	20.7	ND	10	ND
30	O991129F	24.3	0.32	10	3.2
31	O991129F-SP	24.3	0.36	10	3.6

[a] SP 表示分樣樣品

表 26　本研究不沾鍋遷移試驗原始數據彙整表(續)

序號	樣品編號[a]	直徑(cm)	萃出濃度 (ng/mL)	定容體積 (mL)	PFOA 遷移量 (ng)
高溫模擬油					
1	O991123K	18.8	ND	10	ND
2	O991123K-SP	18.8	ND	10	ND
3	O991123L	22.5	ND	10	ND
4	O991123L-SP	22.5	ND	10	ND
5	O991123M	22.1	ND	10	ND
6	O991123M-SP	22.1	ND	10	ND
高溫模擬油→室溫甲醇					
1	O991123P	18.8	0.20	10	2.0
2	O991123P-SP	18.8	0.23	10	2.3
3	O991123Q	22.5	<0	10	ND
4	O991123Q-SP	22.5	<0	10	ND
5	O991123R	22.1	<0	10	ND
6	O991123R-SP	22.1	<0	10	ND
大豆沙拉油品					
1	O990804C	20 (mL)	ND	10	ND
2	O990804C-DP	20 (mL)	ND	10	ND

[a] SP 表示分樣樣品；DP 表示物件重複樣品

表 27　本研究不沾鍋室溫甲醇遷移試驗與 PFOA 檢驗及品管查核結果

序號[a]	樣品編號	遷移面積 (cm^2)	遷移濃度 (ng/cm^2)[b]	RCSS (%)[c]	RPD (%)[d]
1	O990812A	86.5	ND	96.6	0.9
2	O990812C	292.4	0.009	83.5	0.9
3	O990823K	397.4	0.012	77.4	0.9
4	O990823L	386.9	0.005	86.9	0.9
5	O990823M	379.9	0.009	93.3	0.9
6	O990823N	383.4	0.019	84.8	0.9
7	O990823O	277.5	0.021	71.8	0.9
8	O991117H	274.5	ND	87.1	1.2
9	O991117B	482.8	ND	86.0	1.0
10	O991117C	478.9	ND	98.3	11.7
11	O991117D	452.2	ND	89.9	3.1
12	O991117E	329.9	ND	96.2	4.7
13	O991117F	169.6	ND	90.7	5.1
14	O991117G	329.9	ND	96.4	0.2
15	O991117I	268.7	0.008	90.7	9.6

[a] 樣品#1-7 為同一批物件樣品中取一樣品作為重複樣品，故有相同之 RPD。樣品 #8-16 為各溶出液分樣樣品，其遷移濃度、RCSS 及 RPD 為重複分析之平均值。
[b] 定量極限：0.2 ng/mL　(0.005 ng/cm^2)
[c] 回收率要求 60-110%
[d] 相對差異百分比要求<20%

表 28　本研究不沾鍋室溫及高溫遷移之 PFOA 檢驗及品管查核結果之比較

序號	樣品編號	遷移濃度(ng/cm^2)[a]	RCSS(%)[b]	RPD(%)[c]
室溫甲醇				
3	O990823K	0.012	77.4	0.9
6	O990823N	0.019	84.8	0.9
7	O990823O	0.021	71.8	0.9
高溫模擬油				
3	O991123L	ND	94.7	1.4
6	O991123M	ND	90.5	0.3
7	O991123K	ND	94.2	4.4
高溫模擬油→室溫甲醇				
3	O991123Q	ND	84.9	2.3
6	O991123R	ND	86.6	2.6
7	O991123P	0.0078	88.7	13.0

[a] 定量極限：0.2 ng/mL (0.005 ng/cm^2) [b] 回收率 60-110% [c] 相對差異百分比 <20%

表 29　本研究防油紙遷移試驗原始數據彙整表

序號	樣品編號[a]	樣品質量(g)	萃出濃度 (ng/mL)	定容體積 (mL)	PFOA 遷移量 (ng)
室溫甲醇					
1	O990804F	0.99	3.55	10	35.5
2	O990804G	0.98	ND	10	ND
3	O990804H	1.06	ND	10	ND
4	O990804K	1.01	ND	10	ND
5	O990810A	1.03	ND	10	ND
6	O990810B	1.03	ND	10	ND
7	O990810C	1.03	ND	10	ND
8	O990810E	1.02	4.75	10	47.5
9	O990810F	1.01	8.61	10	86.1
10	O990823A	0.94	1.92	10	19.2
11	O990823B	0.94	8.43	10	84.3
12	O990823C	1.01	18.5	10	185
13	O991123U	1.03	11.4	10	114
14	O991123U-DP	1.0	9.53	10	95.3
15	O990823E	0.92	2.41	10	24.1
16	O990823F	1.02	5.87	10	58.7
17	O991123V	1.04	16.3	10	163
18	O991123V-DP	1.0	13.8	10	138
19	O991129G	1.02	4.20	10	42.0
20	O991129G-DP	1.0	4.24	10	42.4
21	O991129H	1.04	0.82	10	8.2
22	O991129H-DP	1.0	0.86	10	8.6
23	O991129I	1.01	ND	10	ND
24	O991129I-DP	1.01	ND	10	ND
25	O991129J	1.0	ND	10	ND
26	O991129J-DP	1.03	ND	10	ND
27	O991129K	1.01	7.81	10	78.1
28	O991129K-DP	1.02	8.20	10	82.0
29	O991129L	1.0	ND	10	ND
30	O991129L-DP	1.02	ND	10	ND

[a] DP 表示物件重複樣品

表 29　本研究防油紙遷移試驗原始數據彙整表(續)

序號	樣品編號[a]	樣品質量(g)	萃出濃度 (ng/mL)	定容體積 (mL)	PFOA 遷移量 (ng)
高溫模擬油					
1	O991123D	1.02	ND	10	ND
2	O991123D-DP	1.0	ND	10	ND
3	O991123E	1.04	ND	10	ND
4	O991123E-DP	1.0	ND	10	ND
5	O991123F	1.01	ND	10	ND
6	O991123F-DP	1.01	ND	10	ND
高溫模擬油→室溫甲醇					
1	O991123G	1.03	8.23	10	82.3
2	O991123G-DP	1.0	7.19	10	71.9
3	O991123H	1.02	6.40	10	64.0
4	O991123H-DP	1.0	6.34	10	63.4
5	O991123I	1.0	3.69	10	36.9
6	O991123I-DP	1.04	4.09	10	40.9

[a] DP 表示物件重複樣品

表 30　本研究食品包裝防油紙室溫甲醇之 PFOA 遷移試驗與品管查核結果

序號[a]	樣品編號	樣品厚度 (mm)	遷移面積 (cm^2)	樣品質量 (g)	遷移濃度 (ng/g)[b]	遷移濃度 (ng/cm^2)[c]	RCSS(%)[d]	RPD[f]
1	O990804F	0.06	202.0	0.99	35.9	0.18	90.6	6.3
2	O990804G	0.04	245.0	0.98	ND	ND	101	6.3
3	O990804H	0.04	250.9	1.06	ND	ND	88	6.3
4	O990804K	0.04	233.5	1.01	ND	ND	110	6.3
5	O990810A	0.48	29.6	1.03	ND	ND	78.6	6.3
6	O990810B	0.48	29.0	1.03	ND	ND	94.5	6.3
7	O990810C	0.04	265.8	1.03	ND	ND	66	6.3
8	O990810E	0.07	215.9	1.02	46.6	0.22	86.2	6.3
9	O990810F	0.04	162.9	1.01	85.2	0.53	79.2	6.3
10	O990823A	0.07	186.1	0.94	20.4	0.1	106	0.9
11	O990823B	0.07	205.5	0.94	89.7	0.41	95.2	0.9
12	O990823C	0.07	186.2	1.01	183	0.99	89.8	0.9
13	O991123U	0.07	208.3	1.02	103	0.50	91.4	15.3
14	O990823E	0.07	193.7	0.92	26.2	0.12	102	0.9
15	O990823F	0.06	207.1	1.02	57.5	0.28	83.1	0.9

[a] 樣品#1-9、# 10-15 分別為二批物件樣品中各取一樣品作為重複樣品，故有相同之 RPD，樣品#13 為溶出液分樣樣品，其遷移濃度、RCSS 及 RPD 均為重複分析平均值。

[b] 定量極限：0.2 ng/mL　(2.0 ng/g)　[c] 遷移濃度以單面面積計算　[d] 回收率 60-110%　[f] 相對差異百分比<20%

表 31　本研究防油紙室溫及高溫遷移之 PFOA 檢驗及品管查核結果之比較

序號	樣品編號	遷移濃度 (ng/g)[a]	遷移濃度 (ng/cm^2)[b]	RCSS(%)[c]	RPD(%)[d]
室溫甲醇					
9	O990810F	85.2	0.53	79.2	6.3
12	O990823C	183	0.99	89.8	0.9
13	O991123U	103	0.5	91.4	15.3
高溫模擬油					
9	O991123F	ND	ND	91.2	0.6
12	O991123E	ND	ND	91.5	2.1
13	O991123D	ND	ND	90.5	2.8
高溫模擬油→室溫甲醇					
9	O991123I	38.2	0.24	87.0	6.4
12	O991123H	63.1	0.34	83.6	1.0
13	O991123G	75.9	0.37	85.2	10.5

[a] 定量極限：0.2 ng/mL　(2.0 ng/g) [b] 遷移濃度以單面面積計算 [c] 回收率 60-110% [d] 相對差異百分比<20%

表 32　本研究建立之三暴露路徑 PFOA 健康風險評估數學模式

數學公式	說明
$ADD_T = ADD_c + ADD_{fw} + ADD_{nf}$ (ng/kg-d)	總 ADD
$ADD_{fw} = TDI \times ER_{fw}$ (ng/kg-d)	食品+飲用水 ADD
$ADD_{nf} = TDI \times ER_{nf}$ (ng/kg-d)	非食品 ADD
$ADD_c = TDI \times (1 - ER_{fw} - ER_{nf})$ (ng/kg-d) $= TDI \times ER_c$	食品接觸物件 ADD
$SML(\frac{ng}{cm^2}) = \frac{ADD_c\ (ng/kg-d) \times BW\ (kg)}{IR_f(\frac{g}{d}) \times \frac{1}{10}(\frac{in^2}{g}) \times \frac{2.54^2}{1^2}(\frac{cm}{in})^2 \times CF}$	特定遷移限值

ADD_T：總均日劑量，單位 ng/kg-d。

ADD_c：食品接觸物件之均日劑量，單位 ng/kg-d。

ADD_{fw}：食物及飲用水暴露之均日劑量，單位 ng/kg-d。

ADD_{nf}：非食品暴露之均日劑量，單位 ng/kg-d。

TDI：每人每日耐受量，等同於總均日劑量，單位 ng/kg-d。

ER_{fw}：食物及飲用水佔 TDI 之比例，50%、60%、70%。

ER_{nf}：非食品暴露路徑佔 TDI 之比例，27%。

ER_c：食品接觸物件佔 TDI 之比例，23%、13%、3%。

SML：不沾鍋及防油紙等食品接觸物件之特定遷移限值，單位 ng/cm^2。

BW：體重，單位 kg (國民健康局, 2008)。

IR_f：每人每日攝食率，單位 g/d (國民健康局, 2008)。

0.1：食品與物件接觸係數(USFDA, 2007)慣用值(10 g food/in^2)之倒數。

2.54^2：in^2 與 cm^2 之單位轉換因子。

CF：物件材質消費比例係數 (USFDA, 2007)。

表 33　本研究研擬之 PFOA 風險評估數學模式之參數選用

參數	選用說明	資料來源
TDI	每日耐受量，歐盟訂定值為 1500 ng/kg-d	EFSA, 2008
ER_{fw}	食物與飲用水暴露路徑佔 TDI 之百分比，保守情境下設定為 50%、60%、70%。	詳見表 35
ER_{nf}	非食品暴露路徑佔 TDI 之百分比，保守情境下之計算為 27%。	詳見表 35
ER_c	食品接觸物件佔 TDI 之百分比。	詳見表 35
CF	物件材質消費比例係數，不沾鍋 0.17，防油紙 0.2。	USFDA, 2007
0.1	食品與物件材質接觸係數慣用值，10 g food/in^2。	USFDA, 2007
2.54^2	單位轉換因子。	
BW	體重，單位 kg。	國民健康局, 2008
IR_f	每日攝食率，單位 g/d。	國民健康局, 2008

表 34　歐盟之食入 PFOA 之 TDI 計算(EFSA, 2008)

Principle study	Perkins et al., 2004	
Critical endpoint	Potential liver effects and hormonal changes for 13- week for male rats at doses of 0, 0.06, 0.64 , 1.94, 6.5 mg/kg/d	
$BMDL_{10}$ (POD)	0.3 mg/kg-d	
Exposure Scenario	General population, dietary exposure in lifetime	
Extrapolation Uncertainty	1. NOAEL	F1 = 1
	2. Subchronic	F2 = 2
	3. Interspecies	F3 = 10
	4. Intraspecies	F4 = 10
Calculation	$TDI = \frac{BMDL_{10}}{UF} = \frac{0.3 \times 10^6}{1 \times 2 \times 10 \times 10} = 1500\ ng/kg - d$	

表 35　本研究研擬之 PFOA 健康風險評估三暴露情境之設定

	低食物+飲用水 暴露情境(A)	中食物+飲用水 暴露情境(B)	高食物+飲用水 暴露情境(C)
食品+飲用水	ER_{fw}：50%	ER_{fw}：60%	ER_{fw}：70%
非食品	ER_{nf}：27%	ER_{nf}：27%	ER_{nf}：27%
食品接觸物件	ER_c：23%	ER_c：13%	ER_c：3%
總計	100%	100%	100%

最大化 ER_{fw}、ER_{nf}之計算：

$$ER_{fw} = \frac{2000\ (\frac{g}{d}) \times 20\ (\frac{ng}{g}) + 1.5\ (\frac{L}{d}) \times 10000\ (\frac{ng}{L})}{60\ (kg)} \div 1500\ {}^{ng}/_{kg-d} \times 100 = 61\%$$

$$ER_{nf} = \frac{20\ (\frac{m^3}{d}) \times 300\ (\frac{\mu g}{m^3}) \times 4000\ (\frac{ng}{g}) \times \frac{1}{10^3}\ (\frac{g}{\mu g}) \div 60\ (kg)}{1500\ \ ng/kg-d} \times 100 = 27\%$$

$$ER_c = 1 - ER_{fw} - ER_{nf}$$

表 36　英國飲用水 PFOA 最大允許濃度(MAC)之計算(UKHPA,2007)

Principle study	UK Committee on Toxicity, 2006b
Critical endpoint	Many adverse effects for studies
NOAEL	0.3 mg/kg-day
Exposure Scenario	Bottle-fed baby, consuming more drinking water on a body basis, in short exposure 1.Body Wight = 5 kg (Bottle-fed baby) 2.Intake Rate = 0.75 L/day 3.Relative source contribution (RSC) = 50 %
Extrapolation Uncertainty	1. NOAEL F1 = 1 2. Subchronic F2 = 1 3. Interspecies F3 = 10 4. Intraspecies F4 = 10
Calculation	$MAC = \frac{0.3 \times 5 \times 0.5 \times 10^3}{10 \times 10 \times 0.75} = 10\ \frac{\mu g}{L}$

表 37　歐盟 PFOA 各路徑比例(EFSA, 2008)

	PFOA	PFOS
Food exposure& Drinking water	>50%	98%
Drinking water	<15% (3.4 mg/L)	<0.5% (0.6 mg/L)
Non-food	<50% Child much more (indoor)	Child much Less
Level in sea food	Lower	Higher (BCF=2000, 50% decay 100 days)
Level in fish liver	Higher in liver than in fillet	
In environment	Widely found	

表 38　本研究不沾鍋食品接觸物件溶出全氟辛酸(PFOA)特定遷移限值(SML_p)之風險評估暴露情境與推估結果

暴露族群	年齡 (yr)	體重[a] (BW, kg) N(Mean, SD)	每日攝食率[b] (IR, kg/d) N(Mean, SD)	物件材質消費比例係數 (CF)	非食物暴露比例 (ER_{nf}, %)	每人每日耐受量(TDI, ng/kg-d)	食物及飲用水暴露比例 (ER_{fw},%)	特定遷移限值 SML_p(ng/cm^2) P50	特定遷移限值 SML_p(ng/cm^2) P95
青少年	7-18	N(46.5,16.4)	N(2.20,0.65)	0.17[c]	27	1500[d]	50	69.5	24.8
							60	39.0	13.7
							70	9.0	3.4
成年人	19-59	N(64.5,41.1)	N(2.26,0.84)	0.17[c]	27	1500[d]	50	84.4	18.3
							60	48.2	10.4
							70	11.2	2.4
老年人	60+	N(62.0,29.6)	N(2.15,0.61)	0.17[c]	27	1500[d]	50	93.4	24.3
							60	52.8	14.3
							70	12.2	3.3

[ab] 2008 年台灣一般民眾暴露參數彙編(國民健康局, 2008)。

[c] 不沾鍋物件材質消費比例係數(USFDA, 2007)

[d] PFOA 每人每日之耐受量(EFSA, 2008)

表 39　本研究防油紙食品接觸物件溶出全氟辛酸(PFOA)特定遷移限值(SML_o)之風險評估暴露情境與推估結果

暴露族群	年齡 (yr)	體重[a] (BW, kg) N(Mean,SD)	每日攝食率[b] (IR, kg/d) N(Mean,SD)	物件材質消費比例係數 (CF)	非食物暴露比例 (ER_{nf}, %)	每人每日耐受量(TDI, ng/kg-d)	食物及飲用水暴露比例 (ER_{fw},%)	特定遷移限值 SML_o(ng/cm^2) P50	特定遷移限值 SML_o(ng/cm^2) P95
青少年	7-18	N(46.5,16.4)	N(2.20,0.65)	0.2[c]	27	1500[d]	50	58.9	20.9
							60	32.9	11.7
							70	7.6	2.7
成年人	19-59	N(64.5,41.1)	N(2.26,0.84)	0.2[c]	27	1500[d]	50	72.0	15.7
							60	40.7	8.6
							70	11.7	1.0
老年人	60+	N(62.0,29.6)	N(2.15,0.61)	0.2[c]	27	1500[d]	50	79.5	22.1
							60	44.7	12.6
							70	10.4	2.8

[ab] 2008 年台灣一般民眾暴露參數彙編(國民健康局, 2008)。

[c] 防油紙物件材質消費比例係數(USFDA, 2007)

[d] PFOA 每人每日耐受量(EFSA, 2008)

表 40　本研究擬定之食品接觸物件 PFOA 特定遷移限值(SML, ng/cm^2)與歐盟/美國之管制限值管制比較表

管制單位/出處	管制限值	說明
本研究 (2010)	• 不沾塗層鍋具 $SML_p = 2.4$ ng/cm^2 • 食品包裝防油紙 $SML_o = 1.0$ ng/cm^2	• 暴露情境設定：三個年齡層 7-18 yr, 19-59 yr, 60+ yr，其中 19-59 yr 為最易感族群。 • 最大化非食品暴露(ER_{nf} = 27%)及食品+飲用水(ER_{fw} = 50, 60, 70%)。 • 引用 USFDA(2007)之 CF,不沾鍋具為 0.17，防油紙為 0.2。 • 使用我國暴露參數：BW, IR_f。 • 進行 Monte Carlo 分析，以 SML 之 P95 值為管制限值。
European Union (2006), Directive 2006/122/ECOF	• 對於紡織品及其他物件塗層之 PFOS 含量需<0.1 ng/cm^2 • 推估 PFOA 含量管制限值為 1 ng/cm^2	• PFOA 之 TDI 為 PFOS 之 10 倍，所以 PFOA 之管制限制可推估為 PFOS 之 10 倍。
European Union, Directive EC/1935/2004 EUROPA>EC>DG Health and Consumers 網站資料庫	• Overall migration limit, OML(T) = DCL = 60 mg/kg food • 尚未訂定 PFOA 管制限值 (2010.12.04 上網查詢)	• 為 Website 資料庫，供食品業者申請食品添加物(FCM)之用，目前共管制 17 大類 FCM，PFOA 屬於 Plastics (9) 之 Additives (9.1)。 • 假設 IR=1 kg/d, BW=60 kg。
Office of Food Additive Safety (OFAS) CEDI/ADI 網站資料庫	• PFOA 管制限值：Dietary Concentration Limit (DCL)=0.12 ppb (ug/kg), Cumulative estitmated daily intake (CEDI) = 6 ng/kg-day • SML= (6 ng/kg-d)(60 kg) (1/3000 d/g)(10 g/in^2)(1 in/2.54 cm)^2 = 0.2 ng/cm^2	• 為 Website 資料庫，供食品業者申請食品添加物(FCS)之用，目前共管制 1267 種 FCS。 • 假設 IR = 3 kg/d, BW = 60 kg。

八、附圖

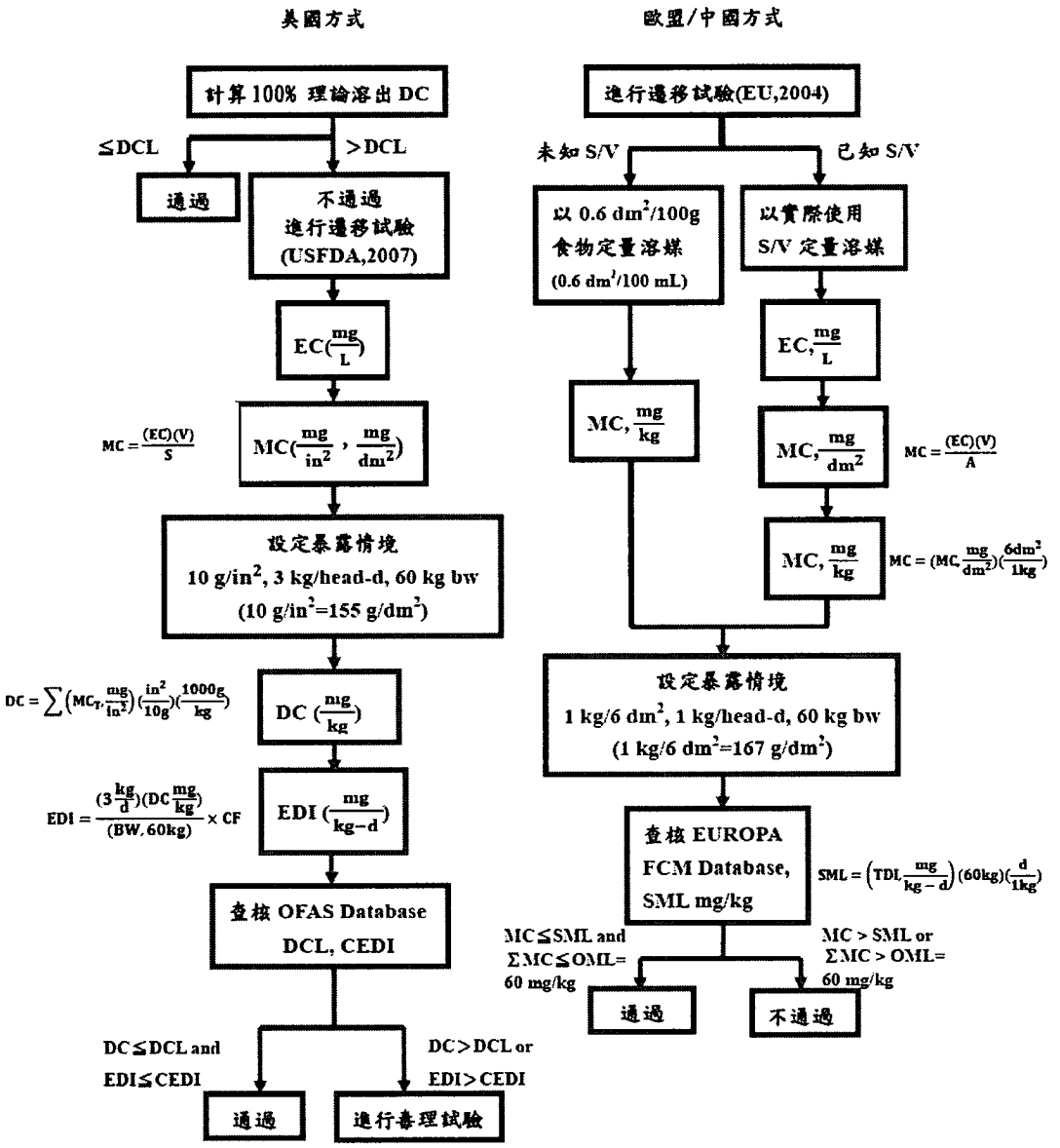


圖 1　美國與歐盟 FCS 管制方法比較

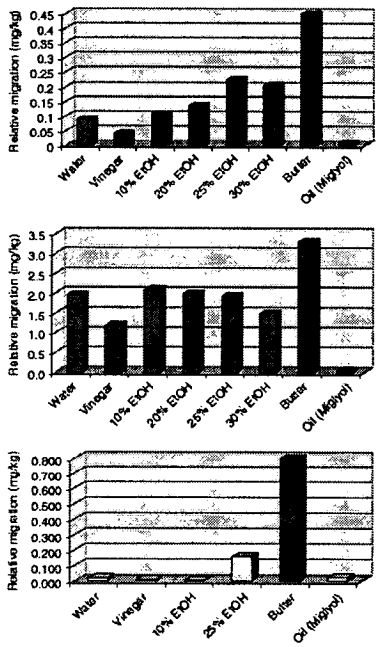


圖 2　於 100^0C，15 min 遷移條件下，防油紙三種全氟化物之溶出量 (Begley et al., 2008)

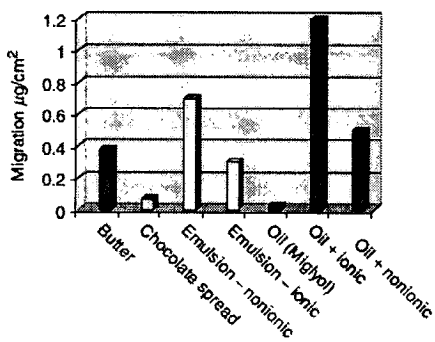
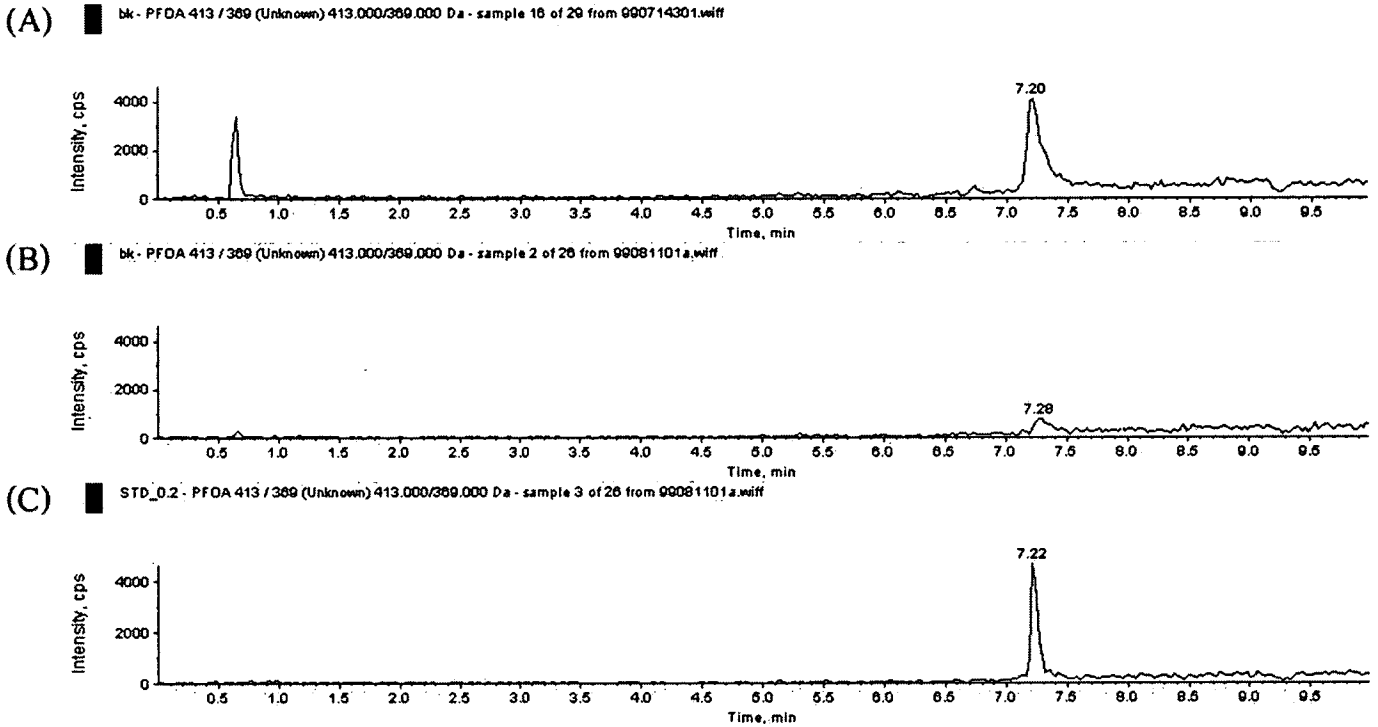
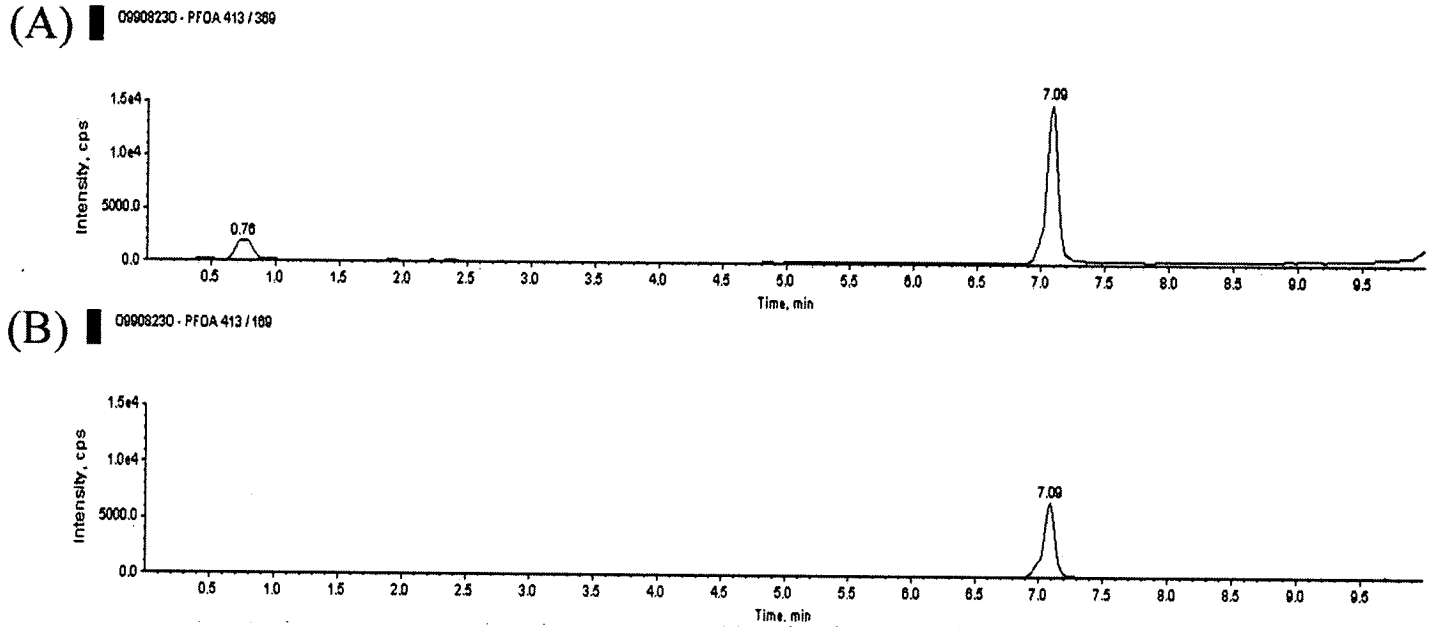


圖 3　於 40^0C，24 小時的遷移條件下，防油紙全氟化物於各種食品模擬物之比遷移量(Begley et al., 2008)



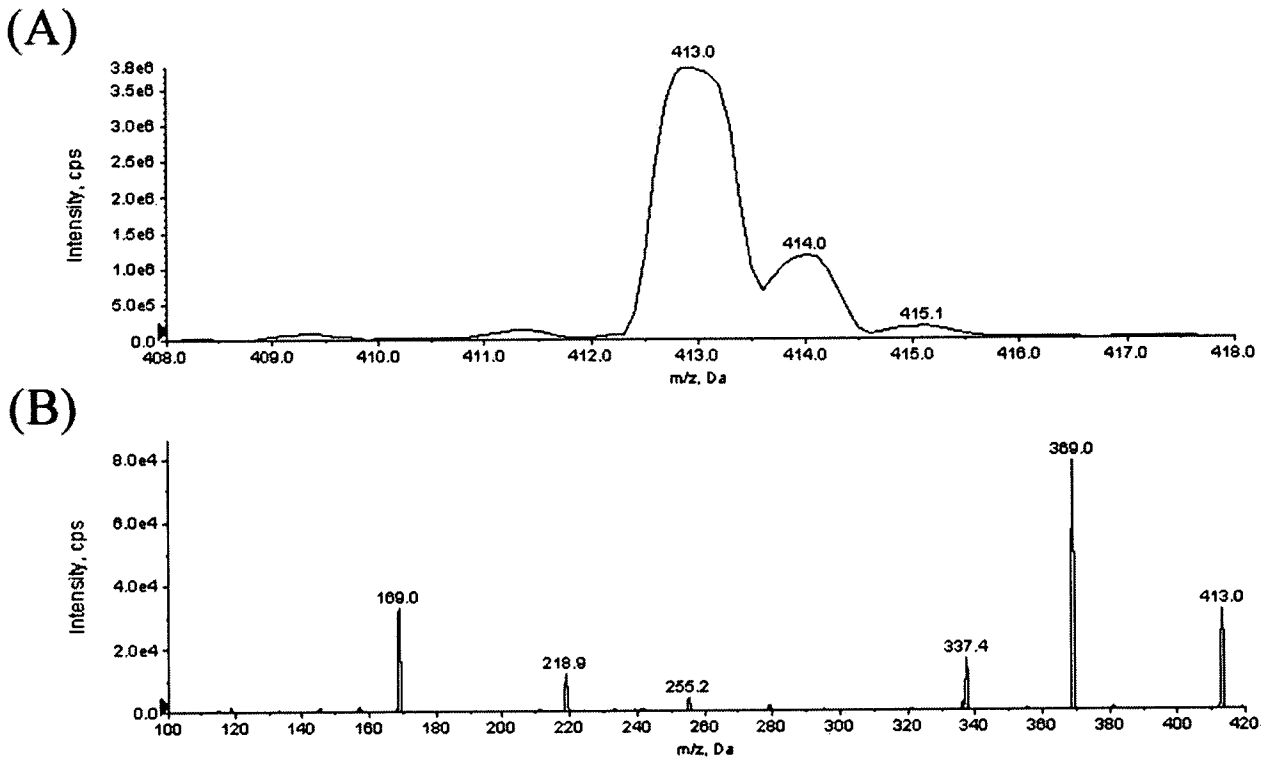
(A)儀器修改前注射空白之上機溶劑，訊號強度 4100 cps(Counts per second)，S/N=46
(B)儀器修改後注射空白之上機溶劑，訊號強度 800 cps，S/N=5.7
(C)儀器修改後注射 2 pg (0.2 ng/mL 注射 10μL) PFOA，訊號強度 4690 cps，S/N=69.3

圖 4　本研究研發 PFOA 檢測方法時，執行之背景干擾查核結果



(A)樣品 O990823O 定量離子對 413/369 之層析圖
(B)樣品 O990823O 定性離子對 413/369 之層析圖

圖 5　本研究檢測不沾鍋樣品之 PFOA 儀器分析圖譜



(A)PFOA 標準品以 single MS scan 之質譜圖

(B)PFOA 標準品取 m/z 值 413.0 以 product ion scan 之質譜圖

圖 6　PFOA 標準品儀器分析圖譜

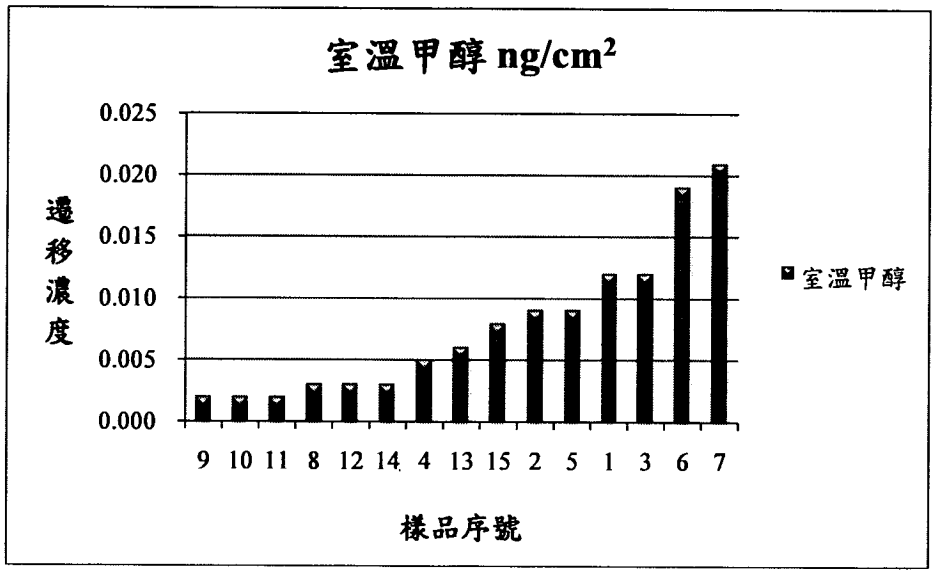


圖 7　本研究不沾鍋室溫遷移濃度分佈圖

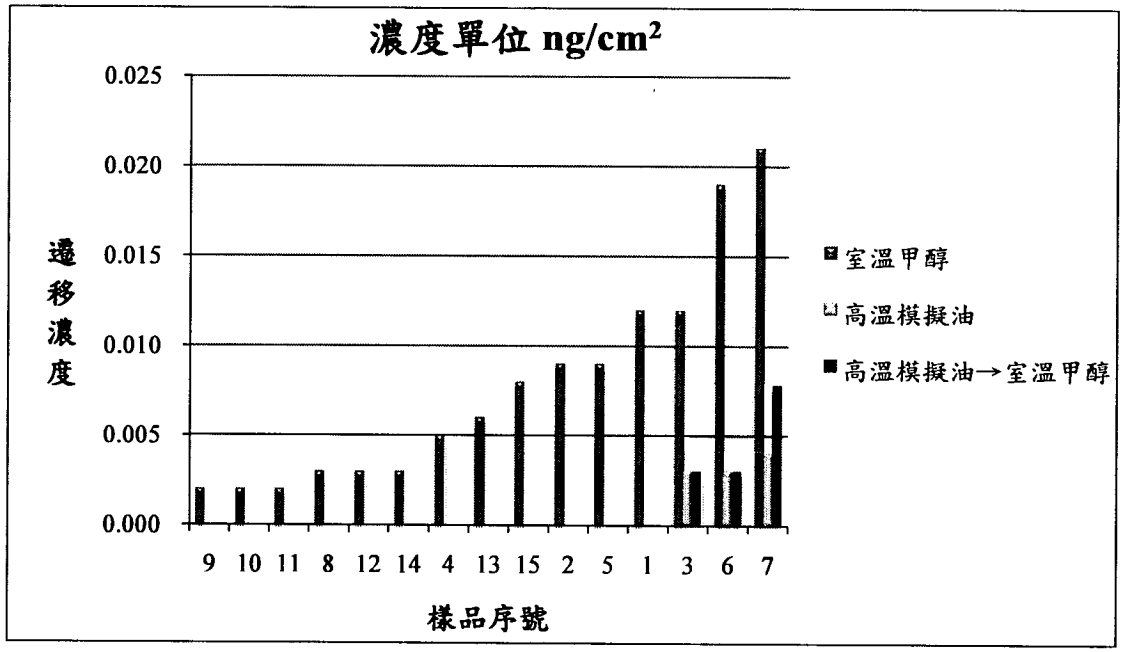
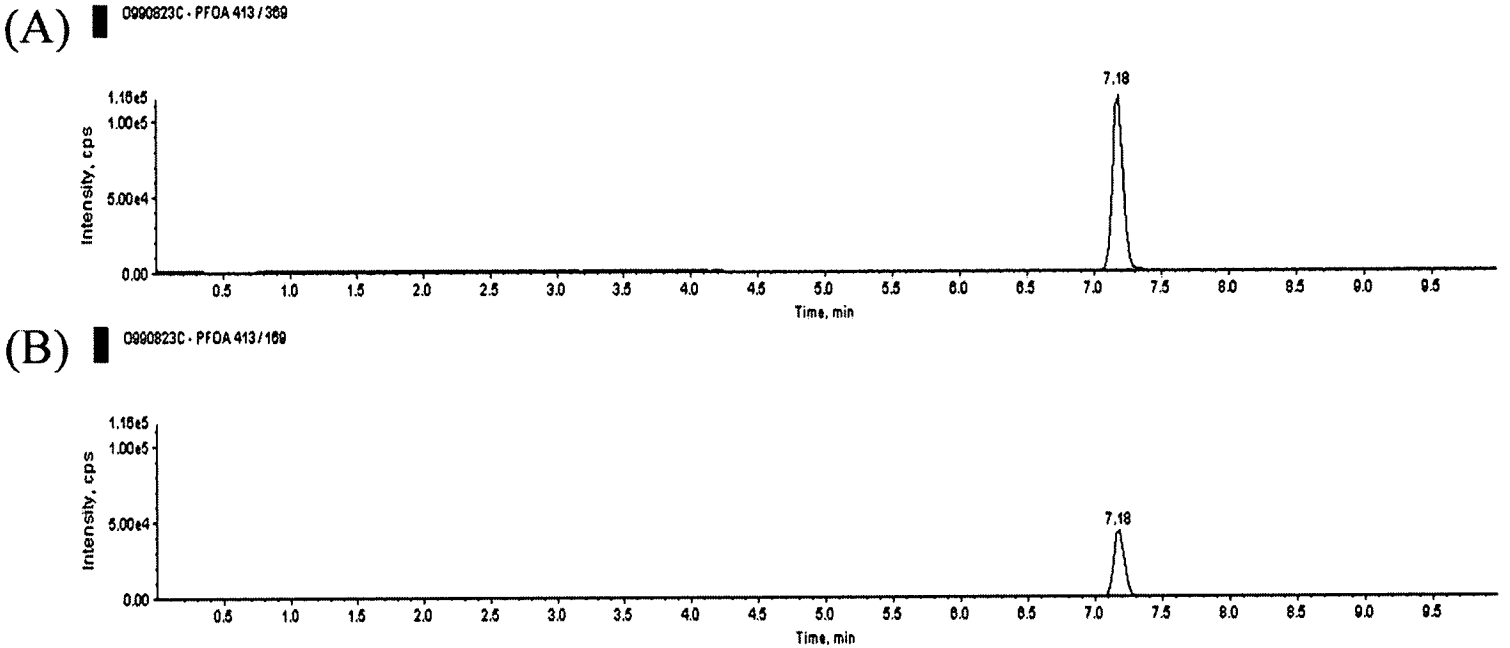


圖 8　本研究不沾鍋三種遷移模式比較分佈圖



(A)樣品 O990823C 定量離子對 413/369 之層析圖
(B)樣品 O990823C 定性離子對 413/369 之層析圖

圖 9　本研究檢測防油紙樣品之 PFOA 儀器分析圖譜

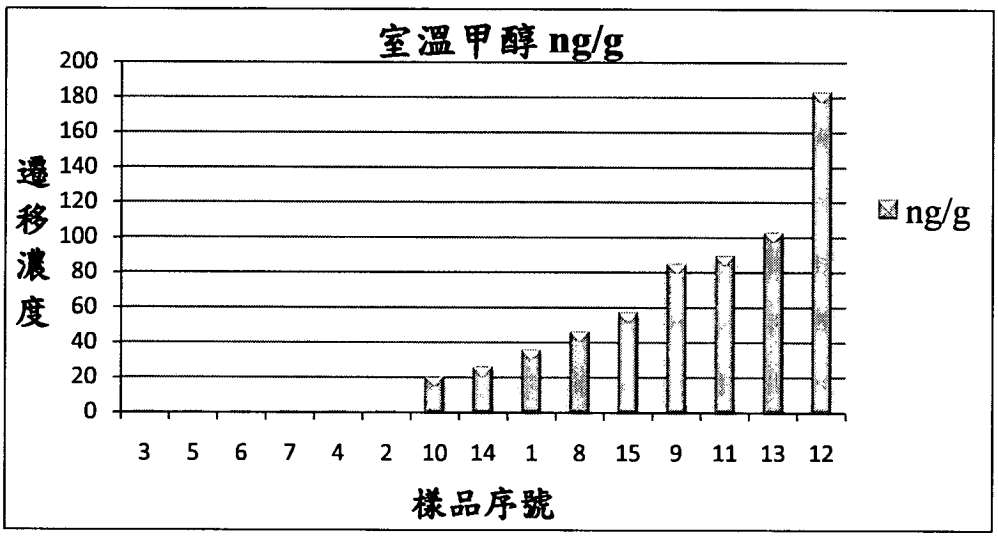


圖 10　本研究食品包裝防油紙室溫甲醇遷移濃度分佈圖(ng/g)

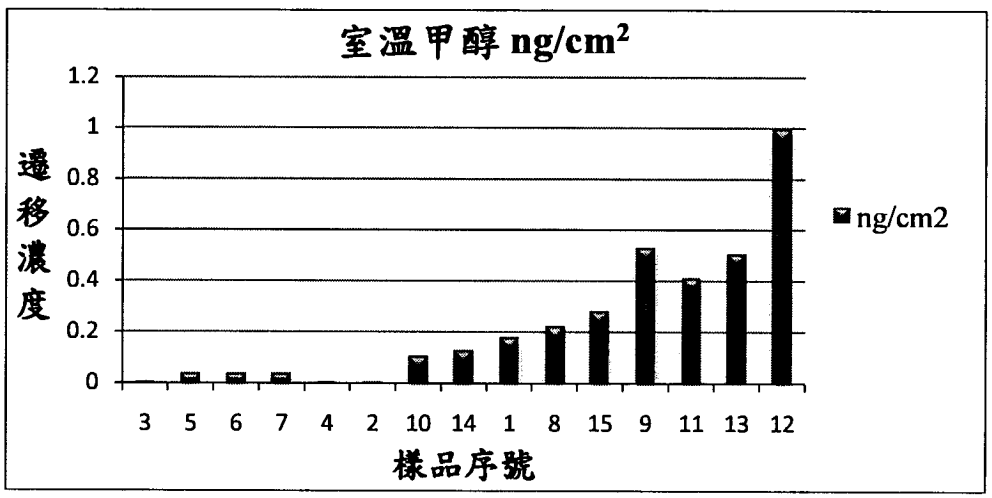


圖 11　本研究食品包裝防油紙室溫甲醇遷移濃度分佈圖(ng/cm^2)

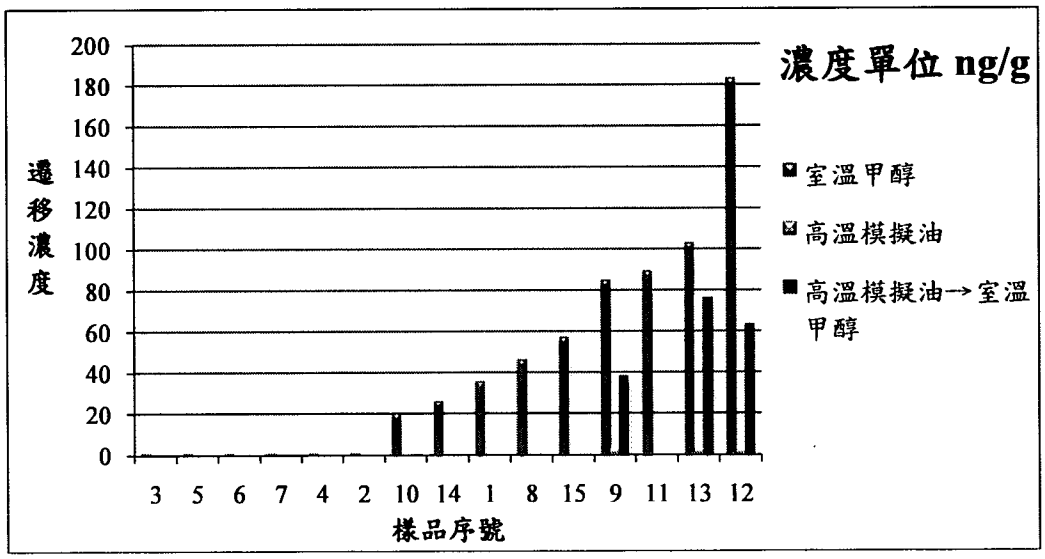


圖 12　本研究食品包裝防油紙三種遷移模式比較分佈圖(ng/g)

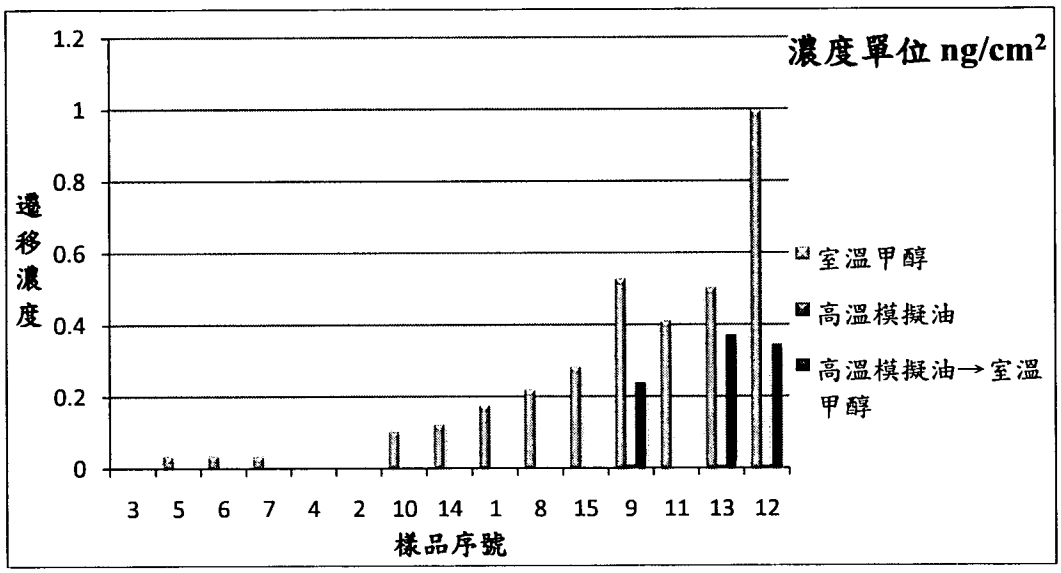


圖 13　本研究食品包裝防油紙三種遷移模式比較分佈圖(ng/cm^2)

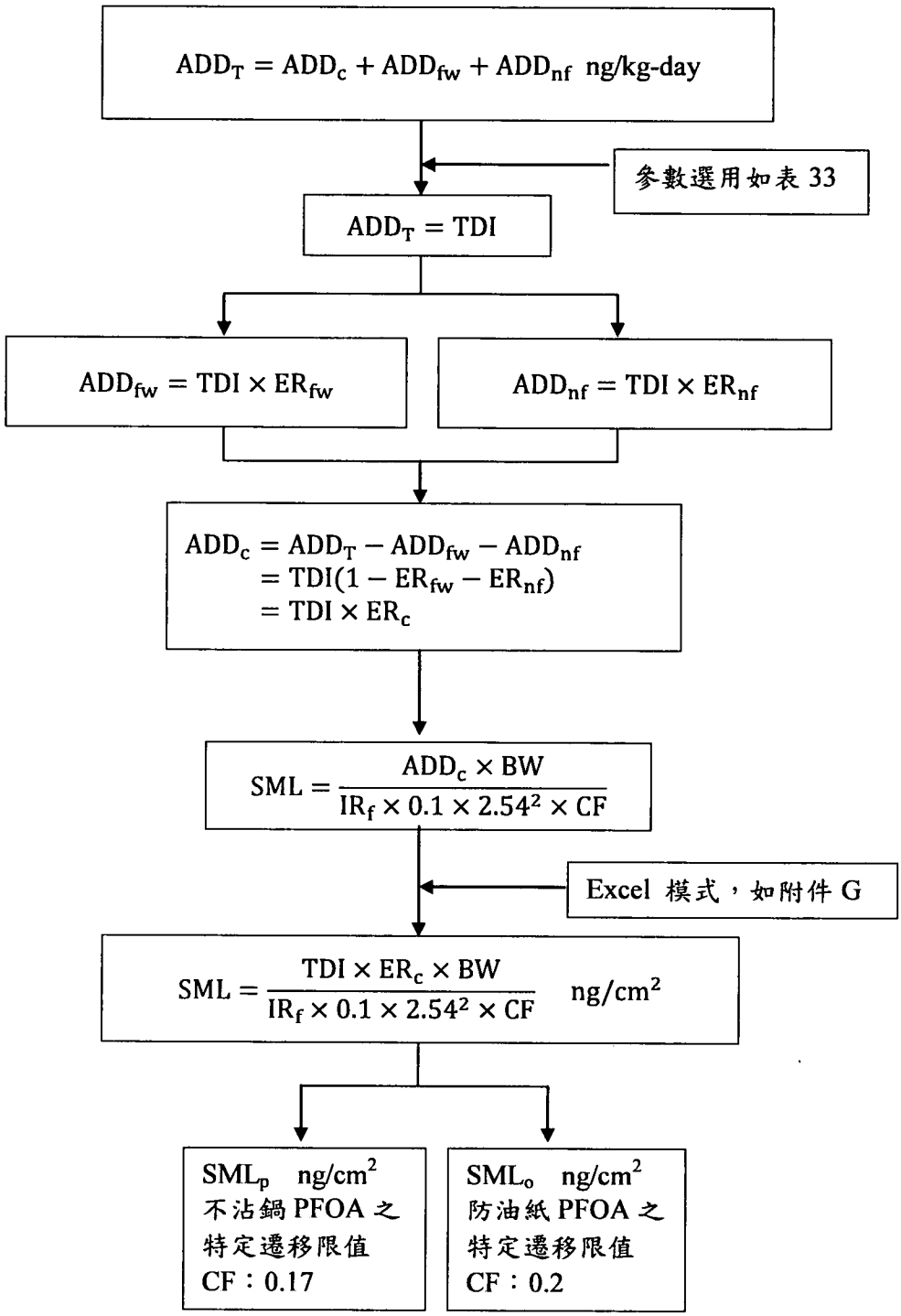


圖 14　本研究研擬之不沾鍋與防油紙之 PFOA 健康風險評估演算法

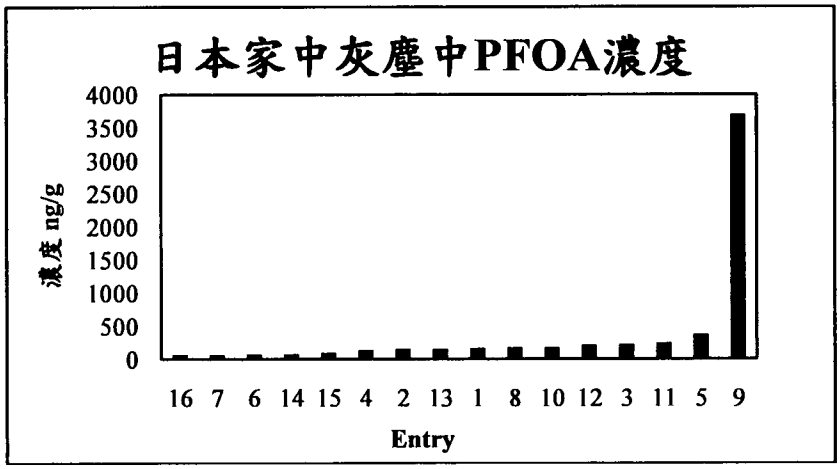


圖 15　日本家中灰塵 PFOA 濃度分佈(Moriwaki et al., 2003)

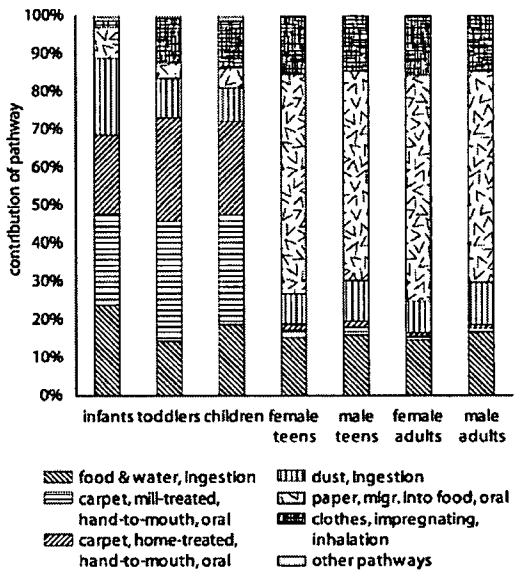


圖 16　北美洲居民 PFOA 各種暴露途徑之比例(Trudel et al., 2008)

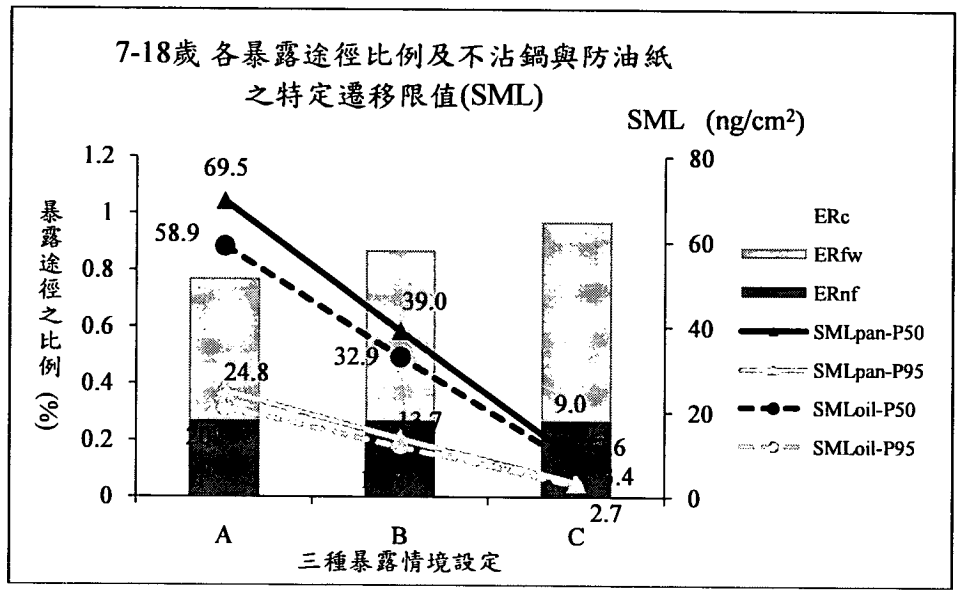


圖 17　本研究模擬之 7-18 歲各路徑劑量比例及不沾鍋與防油紙之特定遷移限值

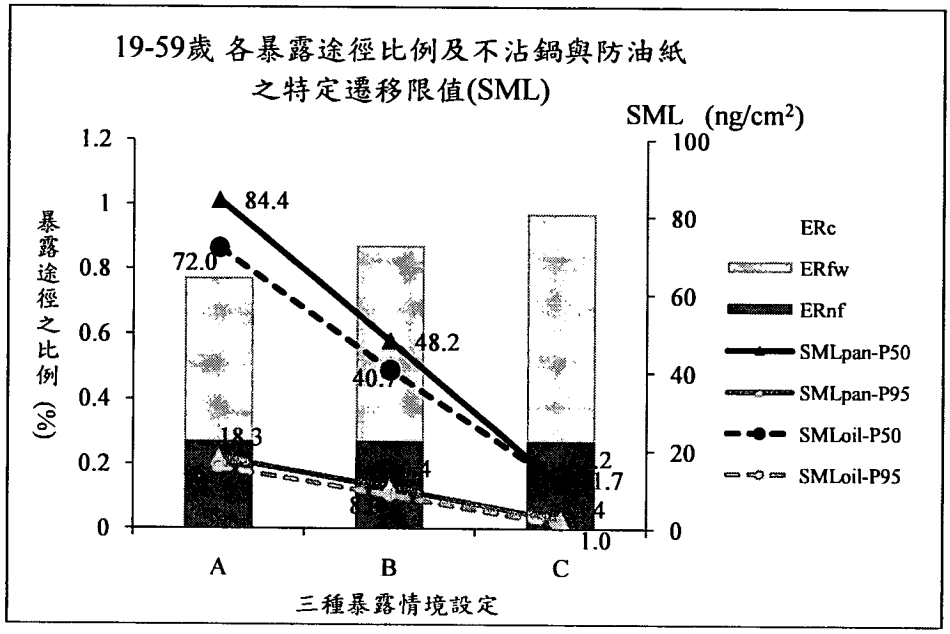


圖 18　本研究模擬之 19-59 歲各路徑劑量比例及不沾鍋與防油紙之特定遷移限值

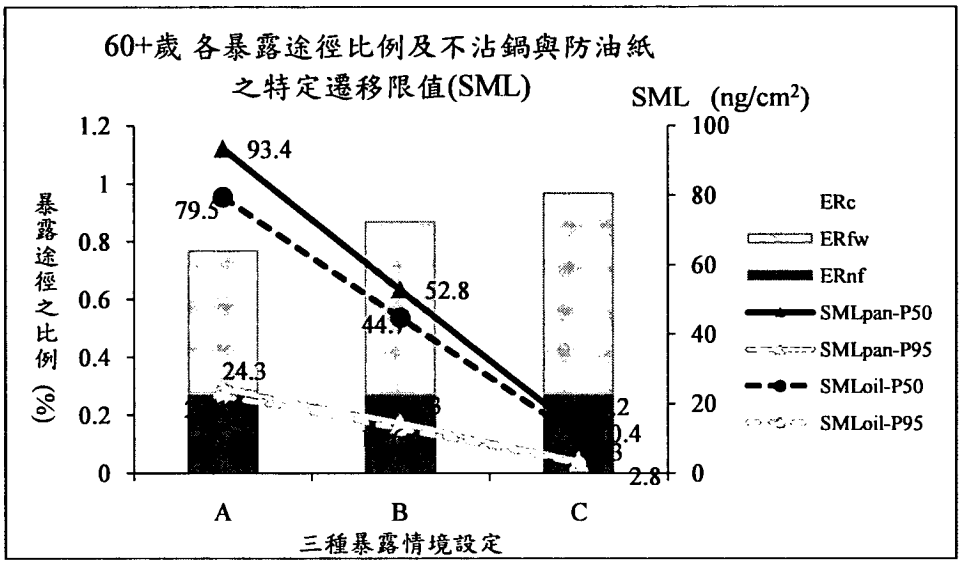


圖 19　本研究模擬之 60+歲各路徑劑量比例及不沾鍋與防油紙之特定遷移限值

附件 A　美國食品藥物管理局 CFSAN(2007)之食品接觸物質業者申請指引

U.S. Food and Drug Administration

Food

Guidance for Industry: Preparation of Premarket Submissions for Food Contact Substances: Chemistry Recommendations

Contains Nonbinding Recommendations

April 2002; December 2007

(This document also available in Chinese†).

Additional copies are available from:
Office of Food Additive Safety
Food and Drug Administration
5100 Paint Branch Parkway
College Park, MD 20740
(Tel) 301-436-1200
http://www.cfsan.fda.gov/guidance.html

U.S. Department of Health and Human Service
Food and Drug Administratio
Center for Food Safety and Applied Nutritio
April 2002; December 200

Contains Nonbinding Recommendations

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2. Table 2. Conditions Of Use

APPENDIX VI. REFERENCES AND FOOTNOTES

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2. Footnotes

Contains Nonbinding Recommendations

Guidance for Industry
Preparation of Premarket Submissions for Food Contact Substances: Chemistry Recommendations

This guidance represents the Food and Drug Administration's (FDA's) current thinking on this topic. It does not create or confer any rights for or on any person and does not operate to bind FDA or the public. You can use an alternative approach if the approach satisfies the requirements of the applicable statutes and regulations. If you want to discuss an alternate approach, contact the FDA staff responsible for implementing this guidance. If you cannot identify the appropriate FDA staff, call the appropriate telephone number listed on the title page of this guidance.

I. INTRODUCTION

This guidance document is intended for industry and contains FDA's recommendations pertaining to chemistry information that should be submitted in a food contact notification (FCN) or food additive petition (FAP) for a food-contact substance (FCS). It is an update to the 2002 guidance,"Preparation of Food Contact Notifications and Food Additive Petitions for Food Contact Substances: Chemistry Recommendations". This updated guidance provides references to assist the reader, sets forth current practice, and clarifies the 2002 guidance based on recent experience with individual sponsors.

A FCS is any substance that is intended for use as a component of materials used in manufacturing, packing, packaging, transporting, or holding food if the use is not intended to have any technical effect in the food (sec 409(h)(6) of the Federal Food, Drug, and Cosmetic Act (the Act)).

A FCS that is a food additive must be regulated for its intended use in 21 CFR Parts 173-178, be exempted from regulation under the agency's Threshold of Regulation Process (21 CFR 170.39), or be the subject of a notification under section 409(h) of the Act that is effective (sec 409(a)(3) of the Act). FCNs and FAPs for FCSs as well as Threshold of Regulation (TOR) Exemption requests must contain sufficient scientific information to demonstrate that the substance that is the subject of the submission is safe under the intended conditions of use (secs 409(h)(1) and 409(b) of the Act). Because the safety standard is the same for all food additives, whether subject to the petition process, the FCN process or the TOR exemption process, the data and information that should be included in all submissions are comparable. Data requirements for TOR Exemption requests are defined in 21 CFR 170.39 and are not dealt with in more detail here.

Section 409(b) of the Act sets forth the statutory requirements for data in an FAP to establish the safety of a food additive. These requirements include descriptions of the following: (1) the identity of the additive, (2 proposed conditions of use of the additive, (3) technical effect data, and (4) methods for the analysis of the additive.

FDA's guidance documents, including this guidance, do not establish legally enforceable responsibilities. Instead, guidances describe the Agency's current thinking on a topic and should be viewed only as recommendations, unless specific regulatory or statutory requirements are cited. The use of the word *should* in Agency guidance means that something is suggested or recommended, but not required.

Throughout the document, the term "sponsor" is used to denote a notifier or petitioner.

II. CHEMISTRY INFORMATION FOR FCNS AND FAPS

A clear and concise presentation of the information in the format described below will facilitate review of th submission. For notifications, references to the corresponding section(s) in FDA Form 3480 (PDF format | Word Template), "Notification for New Use of a Food Contact Substance," are shown in italics.

For those uses resulting in dietary concentrations at or below 0.5 ppb, the data requirements for FCNs or FAPs will be similar to those required for requests submitted under 21 CFR 170.39 (Threshold of Regulation for substances used in food-contact articles. Specifically, the chemistry information requirements will be

similar to those cited in 21 CFR 170.39 (c)(1) and (2). As indicated in 21 CFR 170.39(c)(1), the submission will need to include a description of the chemical composition of the FCS. This would include identity information on the FCS as well as the identities and composition by weight of all likely impurities (*i.e.*, residual starting materials, catalysts, adjuvants, production aids, by-products and breakdown products). Detailed information may be needed where there are specific safety concerns. Providing additional manufacturing information may be the easiest way to address such concerns. For example, manufacturing information may be used to support the conclusion that a volatile chemical is unlikely to remain with the finished FCS because of the high temperatures encountered during the manufacturing process. Similarly, information on the types of solvents used in the manufacturing process along with solubility data of likely impurities may be used to justify a conclusion that an impurity is not likely to be found in the finished FCS. As indicated in 21 CFR 170.39(c)(2), the submission will need to include detailed information on the conditions of use of the substance. This would include a statement describing the technical effect of the substance. FDA has not ordinarily needed data to demonstrate the technical effect for uses that meet the threshold of regulation criteria under 21 CFR 170.39.

A. Identity

(see FDA Form 3480 (PDF format | Word Template)- Part II, Sections A through C)

Identity information is used to describe the FCS that is the subject of a submission and to identify substances that may migrate into food from use of the FCS. Migrating substances may include not only the FCS itself, but also degradation products and impurities in the FCS.

Information identifying the FCS should be as complete as possible with respect to its name, composition, and method of manufacture. These items include:

1. Chemical Name. The Chemical Abstracts or IUPAC name is acceptable.
2. Common or Trade Names. These should not be the only means of identification. FDA does not maintai a compilation of common or trade names.
3. Chemical Abstracts Service (CAS) Registry Number. [2]
4. Composition. A full description of the composition of the FCS is used to compile a list of potential migrants to food. This should include chemical formulae, structures, and molecular or formula weights for single compounds or components of commercial mixtures. For polymers, sponsors should submit the weight average (M_W) and number average (M_n) molecular weight, the molecular weight distribution, and the methods used for their determination. If the molecular weight is not readily obtainable, a sponsor should furnish other properties of the polymer that are functions of the molecular weight, such as intrinsic or relative viscosity or melt flow index.

In addition, sponsors should provide the following information:

a. A complete description of the manufacturing process, including purification procedures, and the chemical equations for all steps of the synthesis.

b. A list of reagents, solvents, catalysts, purification aids, *etc.,* used in the manufacturing process, the amounts or concentrations used, their specifications, and their CAS Registry Nos.

c. Chemical equations for known or likely side reactions occurring during manufacture of the FCS, including catalyst degradation reactions.

d. Concentrations of all major impurities (*e.g.*, residual starting materials, including all reactants, solvents, and catalysts, in addition to byproducts and degradation products) together with supporting analytical data and calculations. In the case of polymers, concentrations of residual monomers should be included.

e. Spectroscopic data to characterize the FCS. In some cases an infrared (IR) spectrum is sufficient, but occasionally other information, such as visible and ultraviolet absorption spectra or nuclear magnetic resonance (NMR) spectra, are more useful.

Those data and information not intended for public disclosure, such as trade secret or confidential commercial information, should be so identified.

5. Physical/Chemical Specifications. Sponsors should submit the physical and chemical specifications of the FCS (*e.g.*, melting point, impurity specifications) as well as properties that can affect migration potential, such as solubility in food simulants. In cases where particle size is important to achieving the technical effect or may relate to toxicity, sponsors should describe particle size, size distribution, and morphology, as well as any size-dependent properties. In the case of new polymers, sponsors should provide glass transition temperatures, ranges for densities and melt flow indices, and information on morphology (*e.g.*, degree of crystallinity) and stereochemistry. For new adjuvants in regulated polymers, sponsors should submit information on the properties of the polymer (*e.g.*, T_g) used in migration testing (see Appendix II. Section 2. for further discussion).

6. Analyses. If the FCS is intended for use as a component of an otherwise regulated material (*e.g.*, an antioxidant in a regulated polymer), sponsors should provide analytical methods for determining the concentration of the FCS in the material. Supporting analytical data should be submitted (refer to Section D.3.).

B. Use

(See FDA Form 3480 (PDF format | Word Template)- Part II, Sections D.1, D.2, and E)

Sponsors should examine general use limitations in effective notifications and regulations for similar FCSs and should include a comprehensive set of limitations on the intended use. Certain of these limitations may be the basis for assumptions made in deriving exposure estimates for the FCS. For an FCN, any applicable limitations can be included in the description of the notified use by way of a draft acknowledgement letter. For an FAP, any applicable limitations should be included in draft language for the applicable regulation. In the absence of appropriate limitations, FDA may be required to use assumptions in estimating exposure that would result in more conservative values for certain classes of FCSs.

Sponsors should provide the maximum use level of the FCS and the types of food-contact articles in which i may be used. "Use level" refers to the concentration of a substance in the food-contact article, not in the food. Sponsors should state the range of possible uses, such as films, molded articles, coatings, etc., and report the anticipated maximum thickness and/or weight per unit area of these articles.

Sponsors should state whether the intended use for the FCS is in single-use or repeat-use food-contact articles. Sponsors should also identify the types of food (with examples) expected to be used in contact with the FCS and the maximum temperature and time conditions of food contact[3]. Classifications for food types and conditions of use that may be helpful are given in Appendix V.

Sponsors should address the stability of the FCS under the proposed conditions of use.

C. Intended Technical Effect

(See FDA Form 3480 (PDF format | Word Template)- Part II, Section D.3)

Sponsors should present data to show that the FCS will achieve the intended technical effect and that the proposed use level is the minimum level required to accomplish the intended technical effect. "Technical effect" refers to the effect on the food-contact article, not on the food. An example would be the effect of a antioxidant in preventing oxidative degradation of a particular polymer. In the case of a new polymer, sponsors should present data that demonstrate the specific properties of the polymer that make it useful for food-contact applications. If technical effect is dependent on particle size, sponsors should present dat that demonstrate the specific properties of the particles that make them useful for food-contact applications. Technical effect information need not be exhaustive and is frequently available in product technical bulletins.

In cases where the use level of an FCS is self-limiting, sponsors should provide supporting information or data.

D. Migration Testing & Analytical Methods

(See FDA Form 3480 (PDF format | Word Template)- Part II, Section F)

Sponsors should provide information sufficient to permit estimation of the daily dietary concentration of the FCS, *i.e.*, consumer exposure. FDA will calculate the concentration of the FCS or other components that might migrate to food expected in the daily diet based on analyzed or estimated levels in food or food simulants. A more complete discussion of this topic is given in Section II.E. and Appendix IV.

The concentration of an FCS in the daily diet may be determined from measured levels in food or in food simulants. It may also be estimated using information on formulation or residual levels of the FCS in the food-contact article and the assumption of 100% migration of the FCS to food. Although FDA always has accepted reliable analyses of FCS in real foods, in practice, many analytes are difficult to measure in food. As an alternative, sponsors may submit migration data obtained with food simulants that can reproduce th nature and amount of migration of the FCS into food. Because an FCS may be used in contact with many foods with different processing conditions and shelf lives, the submitted migration data should reflect the most severe temperature/time conditions to which the food-contact article containing the FCS will be exposed.

Before undertaking migration studies a sponsor should consider carefully the potential uses of the FCS. If, for example, use at temperatures no higher than room temperature is anticipated, it makes little sense to conduct migration experiments that simulate high temperature food contact. Such experiments would lead to elevated levels of the FCS in the food simulants that might, in turn, require a more extensive toxicologica data package to support the exaggerated exposure estimate. In some cases where the use level of the FCS is low, it may be possible to dispense with migration studies altogether by assuming 100% migration o the FCS to food. The following example illustrates this approach:

Consider an adjuvant added prior to the sheet-forming operation in the manufacture of paper. If analysis o calculation shows that the final adjuvant concentration in paper cannot exceed 1 mg/kg and the basis weight of the finished paper is 50 pounds/3000 ft^2, or 50 mg/in^2, then the maximum weight of adjuvant pe

unit area of paper is 1 x 10^{-6} g adjuvant/g paper x 50 mg/in^2 = 0.000050 mg/in^2[4]. If all the adjuvant migrates into food and 10 grams of food contacts 1 square inch of paper (FDA's default assumption), the maximum concentration in food would be 5 µg/kg. It may be expected that this low concentration in food would lead to a commensurately low dietary concentration for the FCS. Therefore, although migration studies might result in further lowering of the estimate of daily intake, such studies might be unnecessary.

Levels in food should be based on the results of migration testing or other applicable methods in order to reflect as closely as possible the actual use conditions of the food-contact article containing the FCS. In general, migration values determined using the assumption of 100% migration to food should be avoided t reduce conservatisms to the greatest extent possible. If a 100% migration calculation is used for an adjuvant in a polymer system, the sponsor should provide a typical polymer thickness. If none is provided default assumption of 10 mil (0.01 in) and the surface are of one side will be used in the calculations.

1. Design of the Migration Experiment *(See FDA Form 3480 (PDF format | Word Template)- Part II, Sectio F, item 1)*

   a. *MIGRATION CELL.* When use of an FCS is anticipated with one particular type of food-contact article, such as a beverage bottle, the article may be filled with a food simulant and tested. For more general uses or when the surface area of the food-contact article does not produce sufficient extractives for adequate characterization, a migration cell should be used in which a specimen of known surface area is extracted by a known volume of simulant. The two-sided migration cell described by Snyder and Breder (Snyder and Breder, **1985**) is recommended. Although this specific cell may not be universally applicable, FDA recommends that two of its essential features be incorporated in modified designs. These are:

      1. Polymer plaques of known surface area and thickness (see Section II.D.1.b. for further discussion) are separated by inert spacers (such as glass beads) so that simulant flows freely around each plaque. Migration from the plaque is considered to be two-sided.

      2. The headspace is minimized, and gas-tight and liquid-tight seals are maintained. (Minimum headspace and gas tightness are of lesser importance if the migrant of interest is non-volatile.)

      Importantly, the cell should be subjected to mild agitation to minimize any localized solubility limitation that might result in mass-transfer resistance in the food simulant.

      For applications in which a two-sided cell design is not suitable, such as laminate constructions, sponsors may refer to the references in Appendix VI for applications describing other cell designs Sponsors also may devise an alternative cell. FDA is willing to comment on any such design prior to its application for a migration experiment.

   b. *TEST SAMPLE.* Some important considerations are the following:

      1. *Formulation:* Sponsors should use the highest proposed concentration of the FCS in the food-contact article in preparing samples for migration testing. Sponsors should provide information that characterizes resin samples used in testing, including the concentrations and identities of other components that may be present, the chemical composition of the resin (including co-monomer content where appropriate), molecular weight range, density, and melt flow index. If the formulation is plasticized, the most highly plasticized formulation should be used for testing.

      2. *Sample Thickness & Surface Area:* Sponsors should report both the thickness of the test plaque and its total surface area. If a plaque is tested by immersion and is of sufficient thickness to ensure that the initial FCS concentration at its center is unaltered by migration that occurs from both sides during the test period, the surface area of both sides may be used to calculate migration (units of mg/in^2).

         Migration may be considered to occur independently from both sides of a sample plaque if it thickness is at least 0.05 cm (20 mil or 0.020 in) and not more than 25 percent of the FCS has migrated by the end of the experiment. If these conditions are not met, the surface are of only one side should be used in the calculation and consideration should be given to proposing a limitation on film thickness.

         Migration from paper is solubility, rather than diffusion, driven therefore paper used in migration tests is considered to be single sided regardless of thickness.

      3. *Polymer properties:* If the FCS is a polymer adjuvant, sponsors should perform migration testing on the polymer with the lowest average molecular weight which complies with the specifications set in 21 CFR 177 (see Appendix II. Section 2. for further discussion). If the FCS is a new polymer, the polymer that would be expected to give the highest levels of extractives, *i.e.,* the polymer with the lowest average molecular weight, percent crystallinity, and degree of cross-linking should be tested.

c. *FOOD SIMULANTS.* The following food simulants are recommended. Additional discussion on this subject is found in Appendix I.

Food-Type as defined in 21 CFR 176.170(c) Table 1	Recommended Simulant
Aqueous & Acidic Foods (Food Types I, II, IVB, VIB, and VIIB)	10% Ethanol[a]
Low- and High-alcoholic Foods (Food Types VIA, VIC)	10 or 50% Ethanol[b]
Fatty Foods (Food Types III, IVA, V, VIIA, IX).	Food oil (*e.g.*, corn oil), HB307, Miglyol 812, or others[c]

[a] for exceptions, see main text.

[b] actual ethanol concentration may be substituted (see main text and Appendix II.).

[c] HB307 is a mixture of synthetic triglycerides, primarily C_{10}, C_{12}, and C_{14}. Miglyol 812 is derivec from coconut oil (see main text and Appendix I.).

When food acidity is expected to lead to significantly higher levels of migration than with 10% ethanol, or if the polymer or adjuvant is acid-sensitive, or if trans-esterification occurs in ethanol solutions, separate extractions in water and 3% acetic acid *in lieu* of 10% ethanol should be conducted. [5]

10% Ethanol is intermediate in alcohol concentration between wine and beer. Migration levels to wine and beer are not expected to be very different from 10% ethanol values. Therefore, test results developed with 10% ethanol may generally be used to evaluate exposures and support clearances for contact with alcoholic beverages with up to 15 volume % ethanol.

Unsaturated food oils (like corn and olive oils) can at times be difficult matrices for the analysis of a migrant because these oils are susceptible to oxidation, especially at high temperature. Miglyo 812, a fractionated coconut oil having a boiling point range of 240° to 270°C and composed of saturated C_8 (50-65%) and C_{10} (30-45%) triglycerides, is an acceptable alternative fatty-food simulant for migration testing.[6] HB 307, a mixture of synthetic triglycerides, primarily C_{10}, C_{12}, and C_{14}, also is useful as a fatty-food simulant.[7]

In some cases, analysis of a migrant in a food oil will not be practical and a simple solvent must be used. There does not appear to be one solvent that will effectively simulate a food oil for all polymers. A list of various polymers and their recommended fatty-food simulants appears in Appendix I. For other polymers, sponsors should consult with FDA concerning use of an appropriate fatty-food simulant before performing migration experiments.

The simulant volume should ideally reflect the volume-to-specimen surface-area ratio expected t be encountered in actual food packaging. A ratio of 10 mL/in^2 is acceptable. Other ratios may be acceptable if migration levels do not approach concentrations reflecting the partition limit (*i.e.*, th solubility of the FCS in the food simulant). Precipitation of the FCS from solution or a cloudy solution is an indication that this limit has been reached. The volume-to-surface-area ratio shoul be reported.

d. *TEMPERATURE AND TIME OF TEST.* Sponsors should conduct migration testing under the most severe conditions of temperature and time anticipated for the proposed use. If the intended use of the FCS involves contact with food at temperatures higher than room temperature, tests should be conducted at the highest use temperature for the maximum expected time period. In many instances, short time periods of elevated temperature-food contact are immediately followed by extended periods of storage at ambient temperatures. For such applications, FDA's recommended migration protocols call for short-term accelerated testing designed to simulate FCS migration that may occur during the entire food-contact period. Recommended protocols for selected situations are given in Appendix II.; however, depending on the particular food-contact application, a specific protocol may be devised.

For room-temperature applications, a test temperature of 40°C (104°F) for 10 days is recommended. This accelerated testing protocol is based on studies showing that experimental migration levels are roughly equivalent to levels obtained after extended storage (6-12 months) at 20°C (68°F) [8].

For refrigerated or frozen food applications, the recommended test temperature is 20°C (68°F).

For polymers, such as polyolefins, that are used with food at temperatures above their glass transition temperatures (*i.e.*, the polymer is in the rubbery state), the highest migration values (typically, but not always, the ten day values) are generally used by FDA to calculate the concentration of migrants in food.

Polymers such as polyethylene terephthalate (PET) and polystyrene (PS), however, are used wit food at temperatures below their glass transition temperatures (*i.e.*, the polymer is in the glassy state). At a fixed temperature, the rate of diffusion of migrants through a polymer in the glassy

state is lower than if the polymer were in the rubbery state. For this reason, accelerated testing for 10 days at 40°C might underestimate migration that would occur during the entire food-contact scenario. Therefore, migration data obtained over ten days at 40°C should be extrapolated to 30 days in order to better approximate migration levels expected after extended time periods at ambient conditions. The sponsor may carry out testing for 30 days to avoid uncertainties in extrapolation. If data are provided that demonstrate that a different extrapolation period is more appropriate for a given adjuvant/polymer combination, such information would be used for evaluating exposure.

For restricted uses where the maximum shelf life and food-contact temperature of an article are known, sponsors are encouraged to carry out migration studies for the maximum shelf life under temperature conditions approximating expected use. Sponsors may want to consult FDA before undertaking such tests.

For each migration experiment, FDA recommends that portions of the test solutions should be analyzed during at least four time intervals. Recommended sampling times for a ten-day test are 2, 24, 96, and 240 hours. FDA recommends analysis of a blank or control using a test cell identica to that used for the test article.

e. *END TESTS (Compliance Tests).* It is important to realize that the appropriate migration test conditions for a new FCS are not those described in 21 CFR 175.300, 21 CFR 176.170 or other sections in 21 CFR. These published "end-test" or compliance test extractions are quality control test methods for verifying whether a particular product is equivalent to the material that served as the basis for the regulation. End tests bear no relation to the migration testing recommended for evaluating probable exposure to a new FCS.

2. Characterization of Test Solutions & Data Reporting *(See FDA Form 3480 (PDF format | Word Template)- Part II, Section F, item 1)*

Sponsors should perform migration studies in triplicate and analyze the test solutions for the migrants.

If the submission is for a polymer, sponsors should determine the amount and nature of total nonvolatile extractives (TNEs). Ordinarily, the TNEs are determined gravimetrically. The nature of the extractives, which may include monomers, oligomers, adjuvants, and catalyst residues, should be determined by suitable chemical or physical tests, such as NMR, ultraviolet (UV)-visible, and atomic absorption spectroscopy (AAS), mass spectrometry (MS), and gas or liquid chromatography (GC or LC) The limit of quantitation (LOQ) and selectivity of the methods should be indicated in the submission. If quantitation of individual migrants is not possible, sponsors should determine the distribution of the extractives between organic and inorganic fractions by solvent fractionation (*i.e.*, the fraction of the TNE residue that is soluble in chloroform or other suitable solvent[9]). This serves, as a first step, to focus on the migrants of interest (*e.g.*, organic components) in determining exposure estimates. In these instances, FDA generally will estimate exposure to TNEs from the use of the FCS assuming that the TNEs (or solvent soluble TNEs) consist solely of low molecular weight oligomers that are chemically equivalent. Because the degree of toxicological testing depends on the magnitude of the exposure estimate, it should be to the sponsor's advantage to quantitate the components in the TNEs that are not chemically equivalent (*e.g.*, differentiate between low molecular weight oligomers and polymer adjuvants).

Test solutions from polymers that are the subject of a submission also should be analyzed for constituent monomers. Alternatively, the known residual monomer level in the polymer may be used t calculate monomer dietary concentrations by using the density of the polymer, the maximum anticipated thickness of the food-contact article, and by assuming that all of the residual monomer migrates into food and that ten grams of food contact one square inch of food-contact article.

If the submission is for a polymer adjuvant, the test solutions are generally analyzed only for the adjuvant. Occasionally, however, it may be appropriate to quantitate, in the test solutions, impurities or decomposition products present in the adjuvant if they might be expected to become components of the daily diet in toxicologically significant quantities. A common example would be the presence of carcinogenic impurities in the adjuvant.

It also may be appropriate to quantitate, in the test solutions, decomposition products produced either as a result of the FCS exhibiting its intended technical effect in the food-contact article or in the test solutions after migration of the FCS. An example would be the use of a new antioxidant for polyolefins. Polymer antioxidants, by their nature, would be expected to partially decompose during thermal processing of the resin or food-contact article to which they have been added. Frequently, decomposition will occur after migration of the FCS into the food or food simulant, where temperature may reach 120°C with fatty-food simulants. Information on decomposition in food simulants may be obtained by conducting stability studies on the FCS in parallel with the migration studies.

Sponsors should report results in terms of milligrams of substance extracted per square inch (mg/in^2) of surface area. Although migration levels often are expressed in terms of mg/dm^2, the mixed unit mg/in^2 is preferred to facilitate conversion to concentration in food. If ten grams of food are in contact

with one square inch of food-contact article surface, a migration of 0.01 mg/in^2 corresponds to a concentration in food of 1 mg/kg. For specialized food-contact applications where an assumed ratio of 10 g food per in^2 is not appropriate, such as in dual-ovenable trays and microwave heat-susceptor applications, sponsors should use the lowest ratio from the actual food-contact applications and should provide justification for the ratio selected.

3. Analytical Methods *(See FDA Form 3480 (PDF format | Word Template)- Part II, Section F, item 1)*

Sponsors should submit the following for each method:

a. *DESCRIPTION OF THE METHOD.* The description should include discussions on the method's accuracy, precision, selectivity, limit of quantitation (LOQ), and limit of detection (LOD). [10] Sufficient detail should be provided so that it can be followed by an experienced analytical chemist. If a literature reference is available, a copy should be included in the submission.

b. *STANDARD CURVES.* Standard curves or calibration curves obtained by analyzing a prepared medium fortified with several known amounts of analyte to obtain concentrations both greater than and less than the concentration of migrant in the test solutions. The prepared medium may be the pure solvent, a solution of known ionic strength, etc. The data points from which the standard curve is derived should bracket the concentration of the migrant in the test solution. Ar analyte concentration of 1 mg/kg determined from a standard curve obtained from concentration of 10, 15 and 20 mg/kg would be unacceptable. The correlation coefficient and standard errors o the Y intercept and the slope should be reported with the standard curve.

c. *EXAMPLES OF SPECTRA OR CHROMATOGRAMS.* Sponsors should submit sample spectra and chromatograms, clearly identifying and labeling all major peaks to avoid ambiguities in interpretation.

d. *EXAMPLE CALCULATIONS.* Sponsors should submit example calculations relating the data obtained from instrumental methods to the reported levels (preferably in milligrams migrants per square inch of sample surface area). The examples should include such information as sample size, concentration/dilution steps, and instrument readings (such as peak area or detector response). Modern data systems typically perform these calculations internally based on a serie of standards. The instrument readings should be extracted from the internal data set. Consult the instructions for the instrument/software package used in the analysis for guidance on providing these data. The examples allow the reviewer to perform a rapid internal check on the reported method.

e. *VALIDATION OF ANAYLTICAL METHODS.* Sponsors should properly validate all analytical methods Validation of a method's intended use and the determination of accuracy and precision usually involves: 1) replicate analyses of appropriate matrices fortified with known amounts of the analyte at concentrations similar to those encountered in the migration studies, and 2) determination of the percent recovery of the fortified analyte. In cases where a polymer adjuvan is the subject of interest, test solutions of the polymer formulated without the adjuvant may serve as the matrix for fortification and recovery measurements. Recovery is defined as the difference between measured analyte levels in the fortified and unfortified matrices. Percent recovery is the recovery divided by the fortified level times 100, *i.e.*, if "a" is the measured level i the unfortified solution, "b" is the measured level in the fortified solution and "c" is the fortification level, then percent recovery equals (b-a)/c x 100.

If migration test solutions are fortified, they should be fortified before analytical workup but afte the prescribed test time, e.g., 240 hours. The actual test solutions must be fortified and not the pure food simulants. Fortification of pure simulants instead of the test simulants is probably the most common deficiency in the validation section of an analytical method. Additionally, as noted in Section II.D.2, the stability of the analyte(s) in the migration test solution should be demonstrated.

Sponsors should perform fortification and recovery experiments using three (3) sets of triplicate samples of the test simulants with each set fortified at a separate level. The fortification levels should be one-half (½), one (1), and two (2) times the measured concentration of the analyte in the food simulant. In the event that the FCS is not detected, sponsors should determine the LOI for the method. For quantifiable levels of the analyte, acceptable recoveries should meet the following criteria:

Levels in food or food simulants[(a)]	Acceptable average recovery	Acceptable relative standard deviation
<0.1 mg/kg	60-110%	<20%
>0.1 mg/kg	80-110%	<10%

[(a)] If 0.001 mg of a substance is extracted from one square inch of packaging material into 10 grams of food or food simulant, the estimated concentration in food is 0.1 mg/kg.

In evaluating the precision of the analytical method, the variability arising from analyses of individual samples can be eliminated by performing triplicate analyses on a homogeneous composite (a blend of the triplicate samples) where practicable.

Other validation procedures may be appropriate depending on the particular analysis. For example, analysis of the same test solution by two independent analytical methods would be acceptable validation. Similarly, the method of standard additions is an acceptable alternative in certain cases, such as metal analysis by AAS. In this case, fortify the matrix at two separate concentrations (at least) in addition to the unfortified concentration, and verify the linearity of the standard addition curve by calculation of the least squares correlation coefficient (r should be >0.995).

Sponsors should submit representative spectra or chromatograms from validation analyses of fortified and blank samples. Spectra or chromatograms of the "blank" will facilitate the verification of the absence of interferences. An illustrative example appears in Appendix III.

4. Migration Database *(See FDA Form 3480 (PDF format | Word Template)- Part II, Section F, item 2)*

Migration data for specific migrant/polymer/food simulant systems at given temperatures that exhibit predictable migration-time behavior (*e.g.,* Fickian diffusion) may be used to predict migration at other temperatures. Thus, the need for migration studies for new applications, which may be difficult to perform in certain cases (*e.g.,* high temperature applications), may be reduced.

For example, migration data obtained over 10 days (240 h) at 40°C that exhibits Fickian behavior, in combination with migration data obtained at other temperatures (*e.g.,* 60°C and 80°C), may be extrapolated by means of an Arrhenius plot to predict migration under retort conditions (121°C/2 h and 40°C/238 h), if no apparent change in polymer morphology, such as glass transition or polymer melting, is expected between 30°C and 130°C. Apparent diffusion coefficients, D, at 121°C for each migrant/polymer/food simulant can be obtained from a plot of ln D vs 1/T(K). Thus, migration for 2 hours at 121°C can be estimated and added to migration after 238 hours at 40°C to obtain total migration expected for retort and ambient storage conditions. The density and thickness of the polymer sample and initial concentration of the migrant in the polymer are also necessary for the calculations.

The FDA migration database is intended as a resource for migration data, including diffusion coefficients and relevant polymer/additive properties. FDA continues to compile migration data from various sources for use in estimating migration levels for FCSs. Reliable migration data, *e.g.,* data that follow Fickian diffusion, provided in support of a premarket submission for a food contact substance would be added to the database. In addition, only migration levels that have been measured at three or more time intervals for a given temperature will be considered for inclusion in the migration database. Sponsors may submit suitable data for inclusion into the database in the form of a letter, as part of a notification or petition, or in a Food Additive Master File (FMF). The FDA migration databas is available upon request from the Division of Food Contact Notifications, premarkt@fda.hhs.gov.

5. Migration Modeling *(See FDA Form 3480 (PDF format | Word Template)- Part II, Section F, item 2)*

As discussed above, migration levels in food are typically estimated based on the results of migration testing under the anticipated conditions of use or under the assumption of 100% migration of the FCS to food. These two approaches are adequate in most instances.

A third alternative involves migration modeling. One simple approach to modeling migration for *specific* migrant/polymer/food simulant systems, based on select experimental data, was discussed above in Section II.D.4. If this approach is taken, the source of any material constants used in the migration modeling should be referenced, whether the source is the FDA migration database or the open literature.

Recently, semi-empirical methods have been developed to determine migration levels using limited or no migration data (see, *e.g.,* (Limm and Hollifield, **1996**) and (Baner, et al., **1996**)). These diffusion models rely on estimation of diffusion coefficients based on the nature of the migrant and the physica properties of the polymer. These models may be useful substitutes for, or additions to, experimental data under limited circumstances. Several caveats should be considered in the application of these diffusion models. First, distribution of the migrant in the polymer is considered isotropic. Non-isotropic distribution, whether intentional or unintentional, would be expected to result in non-Fickian migration. Second, other aspects of migration, such as partitioning, mass transfer, polymer morphology, shape/polarity of the migrant, and plasticization of the polymer are not considered in these models. These factors should be considered carefully when deriving migration levels to food using modeling techniques.

E. CONSUMER EXPOSURE

(See FDA Form 3480 (PDF format | Word Template)- Part II, Section G)

Migration data developed using the procedures outlined in Section II.D. are intended to provide estimates of the highest level of migration to food that might result from the anticipated use of the FCS. FDA

estimates probable exposure to the FCS by combining the migration data with information on uses of food-contact articles that may contain the FCS (*i.e.,* on the fraction of a person's diet likely to contact food-contact articles containing the FCS).

From a given concentration of the FCS in the daily diet, the estimated daily intake (EDI) is calculated as the product of that concentration and the total food intake, assumed to be 3 kilograms per person per day (kg/p/d, solids and liquids). A concentration in the daily diet of 1 ppm corresponds to an EDI of 1 mg FCS/kg food x 3 kg food/p/d, or 3 mg FCS/p/d.

The concentration in the daily diet and the EDI from the subject submission, along with the cumulative EDI (CEDI) from all authorized uses (from FAPs, FCNs and TORs), are used by FDA for the safety evaluation of an FCS. The CEDI of the FCS is used to determine the types of toxicity studies necessary to establish safety under the proposed conditions of use. Toxicological data recommendations for several tiers of CEDIs resulting from all proposed and permitted uses of the FCS, including regulated uses, uses that were the subject of previous FCNs, and the use in the subject FCN, are described in the document entitled "Preparation of Food Contact Notifications for Food Contact Substances: Toxicology Recommendations[1]" available on the Internet at http://www.cfsan.fda.gov/guidance.html.

The approach outlined below is designed to deal with the majority of FCSs intended for single-use. For estimating dietary exposures to components of repeat-use items and articles used in or with food processing equipment, exposure estimates also will consider the amount of food to be contacted during the service life of the food-contact article (see Appendix II. Section 4.).

1. Calculation of Exposure

   a. *CONSUMPTION FACTOR.* The term "Consumption Factor" (CF) describes the fraction of the daily diet expected to contact specific packaging materials. The CF represents the ratio of the weight of all food contacting a specific packaging material to the weight of all food packaged. CF values for both packaging categories (*e.g.*, metal, glass, polymer and paper) and specific food-contact polymers are summarized in Table I of Appendix IV. These values were derived using information on the types of food consumed, the types of food contacting each packaging surface, the numbe of food packaging units in each food packaging category, the distribution of container sizes, and the ratio of the weight of food packaged to the weight of the package. These values, however, may be modified as new information is received.

   When FDA computes exposure to an FCS, it assumes that the FCS will capture the entire market for which it is intended for use. This approach reflects both uncertainties about likely market penetration as well as limitations in the data surveyed. Thus, if a company proposes the use of an antioxidant in polystyrene, it is assumed that the antioxidant will be used in all polystyrene manufactured for food contact. In certain cases where an adjuvant is intended for use in only a part of a packaging or resin category, a lower CF representing the coverage that is sought may be used. For example, if a stabilizer is intended for use only in rigid and semirigid poly(vinyl chloride) (PVC), a CF of 0.05 rather than 0.1 could be used in estimating exposure since only about 50% of all food-contact PVC could contain the stabilizer. Another example is the division of polystyrene into impact and non-impact categories (see Table I, Appendix IV.). To reduce conservatisms, FDA recommends that sponsors submit as detailed information as possible on the anticipated resin or packaging market(s) that may be captured by articles manufactured from the FCS.

   A consumption factor may alternatively be calculated using estimated maximum production volume. Should this consumption factor be used in exposure estimates, the FCS will be limited to an annual production volume at or below the maximum that has been specified. If the market volume expands to beyond the stated production volume, a new notification/petition will need to be submitted to account for the increased consumer exposure.

   When new products are introduced, they will initially be treated as replacement items for existing technology. As noted, FDA generally makes estimates based on the assumption that a new product will capture the entire market. For example, the retortable pouch initially was treated as a replacement for coated metal cans and was assigned a CF of 0.17. As additional information or actual use of the retortable pouch became available, the CF was lowered to 0.0004. In certain cases, the submission of resin or packaging market data may lead to the use of a lower CF.

   b. *FOOD-TYPE DISTRIBUTION FACTOR.* Before migration levels can be combined with CF values to derive estimates of probable exposure, the nature of the food that will likely contact the food-contact article containing the FCS must be known. Migration into a fatty-food simulant, for example, will be of little use in estimating probable exposure if the FCS is used exclusively in or for articles in contact with aqueous food. To account for the variable nature of food contacting each food-contact article, FDA has calculated "food-type distribution factors" (f_T) for each packaging material to reflect the fraction of all food contacting each material that is aqueous, acidic, alcoholic and fatty. Appropriate f_T values for both packaging categories and polymer types appear in Table II of Appendix IV.

   c. *CONCENTRATION IN THE DAILY DIET AND EDI.* FDA uses the following approach for calculating

the concentration of the FCS in the daily diet. The concentration of the FCS in food contacting the food-contact article, <M>, is derived by multiplying the appropriate f_T values by the migration values, M_i, for simulants representing the four food types. This, in effect, scales the migration value from each simulant according to the actual fraction of food of each type that will contact the food-contact article.

$<M> = f_{\text{aqueous and acidic}}(M\ 10\%\ \text{ethanol}) + f_{\text{alcohol}}(M\ 50\%\ \text{ethanol}) + f_{\text{fatty}}(M_{\text{fatty}})$

where M_{fatty} refers to migration into a food oil or other appropriate fatty-food simulant.

The concentration of the FCS in the diet is obtained by multiplying <M> by CF. The EDI is then determined by multiplying the dietary concentration by the total weight of food consumed by an individual per day. FDA assumes that an individual consumes 3 kg of food (solid and liquid) per day (see Appendix IV. for sample calculations):

EDI = 3 kg food/person/day x <M> x CF

d. *CUMULATIVE EXPOSURE (CEDI).* If the FCS already is regulated for other uses in 21 CFR 170-199, has been exempted from the need for a regulation under the Threshold of Regulation (21 CFR 170.39), or has been the subject of previous effective FCNs, the sponsor should estimate the cumulative exposure to the FCS from the proposed and permitted uses (see the example in Appendix IV.). Information on the regulatory status of an FCS may be obtained by inspection of 21 CFR 170-199, searching the CFR on the Government Printing Office (GPO) World Wide Website at http://www.access.gpo.gov/nara/cfr/index.html[2], or contacting FDA directly. Information on effective FCNs or Threshold of Regulation exemptions for an FCS may be obtained through the FDA website or by contacting FDA directly. An estimate of cumulative exposure for the regulated, notified and exempted uses of an FCS can be obtained by contacting FDA. FDA also maintains a database of CEDIs for FCSs on the Agency's internet site (http://www.cfsan.fda.gov).

2. Exposure Refinement

Exposure estimates, in general, will be made using the aforementioned procedures. More refined estimates may be possible, however, with additional information provided in a submission. For instance, subdividing packaging or resin categories could reduce the calculated exposure by lowering the CF for the category. The division of PVC into rigid and plasticized categories and PS into impact and non-impact categories are two examples. Another example is the division of polymer coatings for paper into subcategories, such as poly(vinyl acetate) coatings, styrene-butadiene coatings, etc. If an FCS is to be used solely in styrene-butadiene coatings for paper, use of the CF for polymer-coated paper (0.2, Appendix IV. Table 1) would be a gross exaggeration. As noted above, FDA encourages the submission of information that may be used to subdivide the market(s) anticipated for articles manufactured from the FCS.

In those cases where the nature of the coverage requested may necessitate more detailed information or where a sponsor believes that exposure will be overstated by selecting CF and f_T values from Appendix IV., data of the following type may be submitted to facilitate calculations of CF and f_T for materials likely to contain the FCS:

a. Estimates of the total amount of food in contact with the packaging material determined using either:
   1. package unit data (number of units and their size distribution), or
   2. total weight of packaging material produced for food contact, container size distribution, and ratios of weight of food packaged to weight of package.

b. Characterization of the foods that might contact the food-contact article, along with supporting documentation, and the likely f_T values.

c. Information that would demonstrate that only a fraction of a packaging or resin category would be affected by the coverage sought.

d. Technological limitations that could affect the type of food contacted or the fraction of the diet that might be contacted.

F. LIST OF ACRONYMS AND ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
CAS	Chemical Abstracts Service
CEDI	Cumulative Estimated Daily Intake

CF	Consumption Factor
CFSAN	Center for Food Safety and Applied Nutrition
CFR	Code of Federal Regulations
D	Diffusion coefficient
DC	Dietary Concentration
DFCN	Division of Food Contact Notifications
EDI	Estimated Daily Intake
FAP	Food Additive Petition
FCN	Food Contact Notification
FCS	Food Contact Substance
FDA	Food and Drug Administration
FDAMA	Food and Drug Administration Modernization Act
FMF	Food Additive Master File
FOIA	Freedom of Information Act
f_T	Food-type Distribution Factor
EVA	Ethylene Vinyl Acetate
GC	Gas Chromatography
GPC	Gel Permeation Chromatography
HDPE	High-Density Polyethylene
IR	Infrared
LC	Liquid Chromatography
LDPE	Low-Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
LOD	Limit of Detection
LOQ	Limit of Quantitation
<M>	the concentration of the FCS in food contacting the food-contact article
MS	Mass Spectrometry
M_n	number average Molecular Weight
M_w	weight average Molecular Weight
NMR	Nuclear Magnetic Resonance
OFAS	Office of Food Additive Safety
OMB	Office of Management and Budget
PET	Polyethylene Terephthalate
PP	Polypropylene
ppb	parts per billion (ng/g or µg/kg)
ppm	parts per million (µg/g or mg/kg)
PS	Polystyrene
PVC	Poly(vinyl chloride)
PVDC	Poly(vinylidene chloride)
T_g	Glass Transition Temperature
TNE	Total Non-volatile Extractive
TOR	Threshold of Regulation
UV	Ultra-Violet

G. REFERENCE FORMAT

All published and unpublished studies and information presented in a FCN or petition should be referenced appropriately in the text by citing the author(s) and year of publication. Each published reference should include the names of all authors, the year of publication, the full title of the article, pages cited, and name o publication. For a book, the reference also should include the title of the book, the edition, the editor(s) or authors(s), and the publisher. Reference to unpublished studies should identify all authors, the sponsor of the study, the laboratory conducting the study, the final report date, the full title of the final report, the report identification number, and inclusive page numbers. References to government publications should include the department, bureau or office, title, location of publisher, publisher, year, pages cited, publicatio series, and report number or monograph number.

APPENDIX I. FATTY-FOOD SIMULANTS FOR SPECIFIC POLYMERS

A food oil is the most extreme example of a fatty food. If contact with fatty foods is anticipated, FDA recommends conducting migration studies using a food oil as the food simulant. In addition to food oils, such as corn and olive oil for which extensive migration data already exist, the use of HB307 (a mixture of synthetic triglycerides, primarily C_{10},C_{12}, and C_{14}) as a fatty-food simulant has been recommended. Studies in FDA laboratories have shown that Miglyol 812, a fractionated coconut oil having a boiling range c 240-270°C and composed of saturated C_8 (50-65%) and C_{10} (30-45%) triglycerides, is also an acceptable alternative. Since use of these oils for FCS migration may not always be practicable, the use of aqueous-based solvents that simulate the action of these liquid fats is sometimes necessary. While it seems unlikely that one solvent will be found that simulates the action of a food oil for all food-contact polymers, the following list presents polymers for which adequate data exist to support the use of aqueous-based solvents as fatty-food simulants. The recommendation of these solvents is based upon studies done at FDA, at the National Institute of Standards and Technology (formerly The National Bureau of Standards), and by Arthur D. Little, Inc. under contract to FDA (a list of general references pertaining to these studies is shown in Appendix VI). For polymers other than those listed below, sponsors should consult FDA before undertaking any migration experiments.

1. Polyolefins complying with 21 CFR 177.1520 and ethylene - vinyl acetate copolymers complying with 21 CFR 177.1350	95% or absolute ethanol
2. Rigid poly(vinyl chloride)	50% ethanol
3. Polystyrene and rubber-modified polystyrene	50% ethanol
4. Poly(ethylene terephthalate)	50% ethanol or isooctane

Absolute or 95% ethanol has been found to be an effective fatty-food simulant for polyolefins; however, it appears to exaggerate migration for other food-contact polymers.

Previous test protocols (prior to 1988) recommended the use of heptane as a fatty-food simulant. To account for the aggressive nature of heptane relative to a food oil, division of migration values by a factor of five was permitted. Studies have shown, however, that the exaggerative effect of heptane relative to a food oil varies over orders of magnitude depending on the polymer extracted. *Thus, heptane is no longer recommended as a fatty-food simulant.* However, FDA recognizes that in cases where very low migration is anticipated, such as for inorganic adjuvants or certain highly cross-linked polymers, heptane can be useful due to the ease of analytical workup. Because of the known variance in the exaggerative effect of heptane relative to food oil, if heptane is used, migration values will generally not be divided by any factor unless there is adequate justification.

APPENDIX II. SELECTED MIGRATION TESTING PROTOCOLS

The following migration testing protocols are intended to simulate most anticipated end-use conditions of food-contact articles. These protocols are based on the premise that migration to aqueous- and fatty-base foods is typically diffusion-controlled within the polymer, strongly affected by the temperatures encountere during food contact, and further modified by the solubility of the FCS in the foods. Therefore, migration testing with food simulants at the highest temperatures to be experienced by the food-contact article during food contact is recommended. Testing with actual fatty foods is also an option, although determination of the analytes of interest is often very difficult. In those instances where the expected use conditions are not adequately simulated by these protocols or testing with food simulants at the highest anticipated food-contact temperature is not practical, alternatives to those protocols presented below should be developed in consultation with FDA.

1. General Protocols (Single-Use Applications) Corresponding to Condition of Use

As noted in Appendix I., migration to fatty foods is evaluated using a fatty food, a pure liquid fat, or, alternatively, aqueous ethanol solutions when analytical limitations preclude sensitive analyses. As noted i Section II.D.1.c., migration to aqueous, acidic, and low-alcoholic foods is generally evaluated using 10% ethanol and migration to high-alcohol foods is generally evaluated using 50% ethanol.

The recommended migration protocols given below are intended to model thermal treatment and extended storage conditions for polymers, such as polyolefins, used with food at temperatures above their glass transition temperatures. The extended storage period generally involves testing at 40°C for 240 hours (10 days). As discussed in Section II.D.1.d., migration data obtained at 10 days for polymers used below their glass transition temperature should be extrapolated to 30 days to better approximate migration levels expected after extended storage at ambient conditions.

A. *High temperature, heat sterilized or retorted (ca. 121 ° C (250°F))**

10% Ethanol[(a)]	121°C (250°F) for two hours
Food Oil (*e.g.*, corn oil) or HB307 or Miglyol 812	121°C (250°F) for two hours
50% or 95% Ethanol[(a),(b)]	121°C (250°F) for two hours

[(a)]Requires a pressure cell or autoclave, see Appendix VI. Appropriate safety precautions should be

exercised when using equipment generating pressures above 1 atmosphere. (b)Depends on food-contact layer, see Appendix I.

After two hours at elevated temperatures, the tests should be continued at 40°C (104°F) for 238 hours to a total of 240 hours (10 days). The test solutions should be analyzed at the end of the initial two hour period, and after 24, 96 and 240 hours.

*Conditions of Use A includes reheating or cooking of foods where the temperature is £121 °C (250 °F), or heat-sterilized or retorted under transient temperatures >121 °C (250 °F).

B. *Boiling water sterilized.* The same protocol as for Condition of Use A should be used except that the highest test temperature is 100°C (212°F).

C. *Hot filled or pasteurized above 66°C (150°F).* Solvents should be added to the test samples at 100°C (212°F), held for 30 minutes, and then allowed to cool to 40°C (104°F). The test cells should be maintained at 40°C (104°F) for ten days with samples taken for analysis after the intervals indicated for the previous protocols. If the maximum hot fill temperature will be lower than 100°C (212°F), test solvents may be added at this lower temperature. Alternatively, migration studies should be performed for 2 hours at 66°C (150°F) followed by 238 hours at 40°C (104°F). For the alternative method, the longer time at the lower temperature (2 hours at 66°C vs 30 minutes at 100°C) compensates for the shorter time at 100°C.

Note: migration studies conducted according to condition of use C are only adequate to support conditions of use C through G (not condition of use H).

D. *Hot filled or pasteurized below 66°C (150°F).* The recommended protocol is analogous to that for C except that all test solvents are added to the test samples at 66°C (150°F) and held for 30 minutes before cooling to 40°C (104°F).

E. *Room temperature filled and stored (no thermal treatment in the container).* The sponsor should conduct migration studies for 240 hours at 40°C (104°F). The test solutions should be analyzed after 24, 48, 120 and 240 hours.

F. *Refrigerated storage (no thermal treatment in the container).* The recommended protocol is identical tc that for E except that the test temperature is 20°C (68°F).

G. *Frozen storage (no thermal treatment in the container).* The recommended protocol is identical to F except that the test time is five (5) days.

H. Frozen or refrigerated storage; ready-prepared foods intended to be reheated in container at time of use.

10% Ethanol(a)	100°C (212°F) for two hours
Food Oil (e.g., corn oil) or HB307 or Miglyol 812	100°C (212°F) for two hours
50% or 95% Ethanol(a),(b)	100°C (212°F) for two hours
(a)Requires a pressure cell or autoclave, see Appendix VI. (b)Depends on food-contact layer, see Appendix I.	

I. *Irradiation (ionizing radiation).* We do not have protocols for studies on FCSs that are intended to be irradiated with ionizing radiation. Please consult with FDA to discuss recommended protocols for this use.

J. *Cooking (e.g., baking or browning) at temperatures exceeding 121 °C (250 °F).* For high-temperature oven use (conventional and microwave*), migration testing should be performed at the maximum intended cooking temperature for the longest intended cooking time, using a food oil, or a fatty-food simulant (such as Miglyol 812).

*Test protocols for microwave applications, such as microwave-only containers, dual-ovenable containers and microwave heat-susceptor packaging are specifically discussed in Item 11 below.

2. Adjuvants for Polyolefins

In general, under identical testing conditions, levels of migrants from low-density polyethylene (LDPE) are higher than from high-density polyethylene (HDPE) or polypropylene (PP). Migration studies done solely on LDPE (complying with 21 CFR 177.1520(a)(2)) at 100°C (approximately the highest temperature at which LDPE remains functional) are, therefore, generally sufficient to provide coverage for all polyolefins including PP, which may be used for retort applications. In such a case, the CF for all polyolefins (CF = 0.35) generall will be used instead of the individual CF for LDPE (0.12, see Appendix IV. Table I).

Nevertheless, when seeking coverage for use with all polyolefins, it is usually advantageous to perform migration testing on HDPE, PP and linear LDPE (LLDPE), complying with 21 CFR 177.1520, as well as LDPE. By doing this, actual migration values for these polyolefins, which will likely be lower than those obtained from LDPE, may be used to calculate the EDI.

The specific polymer test sample used in the migration testing should be one that has a morphology typically used in food packaging applications. The test material must comply with specifications set out in 21 CFR 177.1520. In addition to noting which specifications listed in 21 CFR 177.1520 apply, information characterizing the polymer resin, such as molecular weight distribution, melt flow index, and degree of crystallinity should be provided.

The catalyst technology for the manufacture of polyolefins is continually being improved. The choice of a particular catalyst technology for the synthesis of polyolefins such as LLDPE, HDPE, and PP determines thei unique physical properties, such as molecular weight and melt flow index. These factors should be taken into account when selecting the appropriate test polymer for the adjuvant. In addition, an increase in the comonomer content of a copolymer generally results in a lower melt range, lower density, and lower crystallinity in comparison to the homopolymers. Therefore, for the broadest possible coverage of an adjuvant, migration testing should be conducted on LLDPE, HDPE or PP copolymers (not homopolymers) incorporating the highest comonomer level.

3. Adjuvants for Polymers (other than Polyolefins)
Adjuvants for More than One Polymer

The recommended migration testing protocols for polymers other than polyolefins are the same as those in Section 1. of this Appendix. Appendix I. should be consulted for the recommended fatty-food simulant.

If use of an FCS is sought without limitation to specific polymers, sponsors should test with an unoriented LDPE sample complying with 21 CFR 177.1520(a)(2). The test protocol depends on the anticipated conditions of use (refer to Section 1. of this Appendix). If the most rigorous applications correspond to Condition of Use A (Section 1.A.), the test temperature should be the highest temperature at which the polymer remains functional (ca.100°C for LDPE). The CF for all polymers (Appendix IV. Table 1, CF = 0.8) should be used with the migration data to calculate the concentration of the FCS in the daily diet. In general, a lower calculated concentration in the daily diet will result if a series of representative polymers are separately tested and individual consumption factors are applied (refer to the examples in Appendix IV.). Sponsors should consult with FDA to determine which representative polymers should be tested.

4. Articles Intended for Repeated Use

The article should be tested with 10% and 50% ethanol and a food oil (*e.g.*, corn oil) or other fatty-food simulant (*e.g.*, HB307 or Miglyol 812) for 240 hours at the highest intended temperature of use. The test solutions should be analyzed for migration of the FCS after 8, 72, and 240 hours. Sponsors should provide estimates of the weight of food contacting a known area of repeat-use article in a given time period as wel as an estimate of the average lifetime of the article. Together with the migration data, this will allow calculation of migration to all the food processed over the service life of the article.

In the case of an adjuvant in a repeat-use article, FDA strongly recommends an initial calculation of a "worst-case" level in food by assuming 100% migration of the adjuvant over the service life of the article and dividing that value by the quantity of food processed. If this calculated concentration is sufficiently low, migration studies will be unnecessary.

5. Coatings for Cans

The migration testing protocol is usually that outlined in Section 1.A. of this Appendix for high temperature, heat sterilized or retorted products. If broad coverage is sought for all types of coatings, sponsors should consult with FDA to determine which coatings should be tested. For use conditions less severe than retort sterilization at 121°C, follow the migration test protocols outlined in Sections 1.B.-G. of this Appendix which most closely approximate the most severe expected use conditions.

6. Uncoated & Clay-Coated Papers with Latex Binders

These papers are intended for contact with food at temperatures less than 40°C for short periods of time. The recommended protocol is the following:

10% Ethanol	40°C (104°F) for 24 hours
50% Ethanol	40°C (104°F) for 24 hours
Food Oil (*e.g.*, corn oil) or HB307 or Miglyol 812	40°C (104°F) for 24 hours

Migration studies conducted on uncoated or clay-coated papers typically result in a high level of extractives due to the large number of low-molecular weight, soluble components in both paper and paper coatings.

Therefore, when total nonvolatile extractives or solvent-soluble[8] total nonvolatile extractives are determined for a paper coating, do not subtract the corresponding extractives from uncoated paper as a blank correction. Rather than using paper as a support for the coating, it is often useful to apply the coatin to a suitable inert substrate, such as glass or metal, for use in migration testing. For a new adjuvant in paper coatings, the test solutions should be analyzed for the unregulated adjuvant. For a new polymer used in paper coatings, the test solutions should be analyzed for constituent oligomers and monomers.

7. Specially Treated Papers

This class includes such types as fluoropolymer- and silicone-treated papers that have oil- and/or heat-resistant properties. The specific protocol depends on the particular uses anticipated. It is recommended that the sponsor either devise a protocol and submit it to FDA for comment or request comment from FDA about appropriate test conditions.

8. Adhesives (Room temperature or below)

If the adhesive is either separated from food by a functional barrier, or the quantity of adhesive that contacts aqueous and fatty food is limited to the trace amount at seams and edges, then migration levels for the substances generally will be assumed to be no greater than 50 ppb. Applying a CF of 0.14 for adhesives gives a dietary concentration of 7 ppb. If these assumptions cannot be supported, data or calculations should be submitted to model the intended use of any adhesive component. If a sponsor wishes to perform migration testing, multilaminate samples should be fabricated with the maximum anticipated amount of the adhesive component and with the minimum thickness of the food-contact layer. The migration protocol corresponds to condition of use E. Alternatively, migration levels in food can be estimated based on migration modeling (see Section II.D.5.).

9. Laminates & Coextrusions

Components of multilayer structures used above room temperature are the subject of two regulations. One covers laminates used in the temperature range 120°F (49°C)-250°F (121°C) (21 CFR 177.1395) and the other covers laminate structures used at temperatures of 250°F (121°C) and above (21 CFR 177.1390). Layers not separated from food by barriers preventing migration during expected use must be listed in these regulations, or be the subject of an effective FCN, unless they are authorized elsewhere for the intended use conditions as specified in 21 CFR 177.1395(b)(2) and 21 CFR 177.1390(c)(1). Test protocols presented in Sections 1.A.-J. may be appropriate for evaluating the level of migration from non-food-contac layers of some laminate structures. End uses that differ considerably from those considered in this guidance, however, should be the subject of special protocol development in consultation with FDA.

10. Boil-In-Bags

Use of the protocol for Condition of Use C is recommended.

11. Special Cooking Applications

Advances in packaging technology have led to the development of food packaging materials that can withstand temperatures substantially exceeding 121°C (250°F) for short periods of time for the purposes c heating and cooking of ready-prepared food. FDA recommends use of the following protocols for migration testing of microwave-only containers, dual-ovenable containers, and microwave heat susceptor materials.

A. *MICROWAVE-ONLY CONTAINERS*

The temperature ultimately experienced by a food-contact material when cooking foods in a microwave oven is dependent on many factors. Some of these are food composition, heating time, mass and shape of the food, and shape of the container. For example, food with mass in excess of 5 g/in^2 container surface area and having a thick shape will require longer cooking times to achieve the desired degree of interior cooking than if it had a lower mass-to-surface area ratio and were thinner. Typical cooking conditions have been generally observed to not exceed 130 °C (266 °F). Test performed for broad coverage in packaging under the protocol for condition of use H (above) will also be adequate to model migration for microwave-only containers. However, for those sponsors that propose use of a food-contact article specifically in microwave containers, migration testing should be performed in a food oil, or fatty-food simulant, at 130 °C (266 °F) for 15 minutes and in an aqueous-food simulant at 100 °C (212 °F) for 15 minutes.

B. *DUAL-OVENABLE TRAYS*

For high-temperature oven use, migration testing should be performed at the maximum intended conventional oven cooking temperature for the longest intended cooking time, using a food oil, or fatty-food simulant (such as Miglyol 812).

C. *MICROWAVE HEAT-SUSCEPTOR PACKAGING*

The high temperatures attained by packaging using susceptor technology may result in (a) the formation of significant numbers of volatile chemicals from the susceptor components and (b) loss of barrier properties of food-contact materials leading to rapid transfer of nonvolatile adjuvants to foods Studies by FDA, with hot vegetable oil in contact with a susceptor, have shown that the susceptor materials liberate volatile chemicals that may be retained in the oil at parts-per-billion (ppb) levels. FDA recommends the use of the protocol outlined in an article by McNeal and Hollifield (McNeal and Hollifield, **1993**) for the identification and quantification of *volatiles* from susceptors.

To isolate and identify the total available *nonvolatile* extractives, sponsors should perform Soxhlet extractions on finely shredded portions of laminated susceptor materials using polar and nonpolar solvents as outlined in Appendix X1 of ASTM method F1349-91. Migration protocols for *UV-absorbing nonvolatiles* also are outlined in ASTM method F1349-91 and in an article by Begley and Hollifield (Begley and Hollifield, **1991**). The ASTM method relies on the determination of a time-temperature profile based on cooking a food product according to label directions, for the maximum cooking time. The temperature reached by a microwave heat-susceptor, however, is dependent on the amount and characteristics of the food product. Testing methods should involve a standard set of conditions that represent the maximum anticipated use conditions. Therefore, FDA recommends that migration studie be conducted in a manner similar to that outlined in the article by Begley and Hollifield. The

recommended standard test conditions are as follows:

1. use laminated susceptor stock representative of the proposed application(s);
2. use a microwave oven with an output wattage of at least 700 watts;
3. use a maximum microwave time of 5 minutes;
4. use an oil mass-to-susceptor surface area on the order of 5 g/in^2; and
5. use a water load on the order of 5 g/in^2.

Exposure estimates may be based, in the absence of validated migration studies, on the assumption of 100% migration of the total nonvolatile extractives to food, as determined by Soxhlet extractions.

Validated migration protocols for the direct determination of aliphatic migrants are not available at this time. However, the amount of aliphatic migrants may be estimated by subtracting the UV-absorbing nonvolatiles and inert materials from the total nonvolatiles obtained by Soxhlet extraction (see Appendix X1 in ASTM method F1349-91). Exposure estimates for aliphatic migrants should be based on the assumption of 100% migration to food.

12. Colorants for Plastics

Some colorants, pigments in particular, may be quite insoluble in the food simulants 10%- and 95%-ethanol. In such cases, solubility information may provide a basis for an alternative to migration testing for evaluating worst-case exposure since migration levels would not be expected to exceed the limits of solubility of the colorant at the proposed use temperature. If the colorant is to be used in all plastic packaging, for which a CF = 0.05 would be used, a solubility below ca. 100 µg/kg at 40°C would lead to a dietary concentration no greater than 5 ppb under conditions as severe as condition of use E (40 °C for 24 hours). A solubility less than 10 µg/kg would lead to an exposure below the threshold level of 0.5 ppb dietary concentration (see 21 CFR 170.39).

13. Dry Foods with Surface Containing No Free Fat or Oil
(21 CFR 176.170(c), Table 1, Food Type VIII)

Dry foods with the surface containing no free fat or oil typically exhibit little to no migration, although some studies have shown migration of certain adjuvants into dry foods (*e.g.*, volatile or low molecular weight adjuvants in contact with porous or powdered foods). If the FCS is intended for use *only* with dry foods with surface containing no free fat or oil, a migration of 50 ppb may be assumed. This migration level can then be multiplied by the appropriate food-type distribution factor and consumption factor to obtain an estimated dietary concentration. If the intended use for the FCS includes other food types (*e.g.*, acidic, aqueous, or fatty foods), in addition to dry foods with surface containing no free fat or oil, then the migration studies conducted for those food types will subsume any migration for a dry food with surface containing no free fat or oil. If you desire to conduct migration studies for dry foods containing no free fat or oil, consult with FDA for recommended migration protocols.

14. Wet-End Additives used in the Manufacture of Paper and Paperboard

Paper additives used in the wet-end of papermaking include those designed to improve the papermaking process, such as processing aids, and those designed to modify the properties of the paper, such as functional aids. Functional aids, mostly organic resins or inorganic fillers, are designed to bond to the paper fibers and, thus, are substantive to paper. For those FCSs that are substantive to paper, migration studies should be conducted and the test solutions analyzed for constituents of the substance. For example, in the case of a polymeric retention aid, the test solutions should be analyzed for constituent oligomers and monomers. On the other hand, processing aids are intended to remain with the process water slurry and, thus, are generally not substantive to paper. Exposure estimates for non-substantive additives may be based on migration studies, or alternatively, on scenarios involving partitioning of the additive between paper fibers and slurry water. The following example illustrates this approach:

Consider an adjuvant added prior to the sheet-forming operation in the manufacture of paper. The intended use level is reported to be 10 mg/kg in the slurry. Since the additive is not substantive to paper, the mass of water (containing the additive) in contact with the pulp at the point in the papermaking proces where the slurry enters the drier determines the level of the adjuvant retained in paper. Prior to entering the driers, the slurry is mechanically concentrated to contain approximately 33% pulp and 67% water. This corresponds to an adjuvant level of 20 mg/kg relative to the pulp. Assuming that finished paper contains 92% pulp, a paper basis weight of 50 mg/in^2, 100% migration of the adjuvant to food, and that 10 g of food contacts 1 in^2 paper, this results in an adjuvant concentration in food of 0.09 mg/kg, or 90 µg/kg. Applying a CF of 0.1 for uncoated and clay-coated paper gives a dietary concentration of 9 ppb.

15. Materials for use during the Irradiation of Prepackaged Food

We do not currently have protocols for studies on FCSs that are intended to be irradiated. Please consult with FDA to discuss recommended protocols for this use.

16. Degradable Polymers or Reactive FCSs

The notifier should include detailed information on the intended use and address the stability of the FCS during the intended use conditions. The degradation or reaction mechanism of the FCS should be describe thoroughly, and should include structural diagrams of possible degradation products and intermediates. Stability and migration testing of the FCS should be conducted with analysis for TNVs, oligomers, breakdown products, and other impurities. GPC analysis before and after extraction tests is recommended to determine changes, *e.g.,* in the molecular weight distribution or the level of low molecular weight oligomers. For migration studies, the samples should be sufficiently aged under appropriate conditions to account for degradation during storage of the FCS (before use) and the shelf-life (during use) of the food-contact article. The sponsor should address whether accelerated migration studies are appropriate for the reaction mechanism. If the FCS will be stored before use, additional stability testing to analyze the effects of exposure to potentially extreme ambient conditions during storage is recommended.

APPENDIX III. ILLUSTRATIVE EXAMPLE OF VALIDATION OF ANALYSES

Polyethylene film containing a new antioxidant was subjected to migration testing with 10% ethanol. The test solutions were analyzed for antioxidant migration. Tests were carried out in separate cells each containing 100 in^2 of film. Four sets of test solutions (in triplicate) were analyzed at 2, 24, 96 and 240 hours for a total of 12 test solutions. After each time interval, each solution from one set was evaporated t dryness, the residue dissolved in an appropriate organic solvent, and a known aliquot injected into a gas chromatograph.

Validation experiments are carried out with the set of test simulants exhibiting the highest level of antioxidant migration. To validate the analytical method, an additional three sets (in triplicate) using 10% ethanol can be run for 240 hours. Each set of these test solutions then can be fortified with the antioxidant at levels corresponding to one-half (1/2), one (1) and two (2) times, respectively, the average migration value determined for the regular (unfortified) 240 hour test solutions.

Instead, the sponsor decided to carry out one large test using enough film and solvent for twelve analyses (three at each of the four time intervals). After 240 hours, the test solution was divided into twelve (12) equal solutions (*i.e.*, four sets of triplicate samples). One set (three solutions) was found to contain antioxidant at an average level of 0.00080 mg/in^2. This value corresponds to 0.080 mg/kg in food if it is assumed that 10 grams of food contacts 1 in^2 of film. Of the remaining nine solutions (three sets), three solutions were fortified at concentrations corresponding to 0.00040 mg/in^2, three were fortified at 0.00080 mg/in^2, and three were fortified at 0.00160 mg/in^2. Each solution was worked up and analyzed as described above. To illustrate the recovery calculations, the results for the set of three solutions fortified at one-half times the average migration (0.00040 mg/in^2) are summarized in the following table:

Measured Level in each Sample (mg/in^2)[(a)]	Recovery (mg/in^2)[(b)]	Percent Recovery (%)[(c)]
0.00110	0.00030	75.0
0.00105	0.00025	62.5
0.00112	0.00032	85.0

[(a)]includes 0.00040 mg/in^2 fortification.
[(b)]calculated by subtracting the average level (0.00080 mg/in^2) from the measured levels in each sample.
[(c)]calculated by dividing the recovery by the fortification level (0.00040 mg/in^2), and multiplying by 100 (see Section II.D.3.e.).

The average percent recovery is 74.2%, and the relative standard deviation is 15.2%. These are within the limits specified (see Section II.D.3.e.) for a concentration in food of 0.080 mg/kg (percent recovery 60-110%, relative standard deviation not exceeding 20%). If the corresponding percentages for the other two fortification levels are also within these limits, the validation for the 10% ethanol migration studies would be acceptable. The actual validation procedure used will, of course, depend on the particular type of analysis.

APPENDIX IV. CONSUMPTION FACTORS, FOOD-TYPE DISTRIBUTION FACTORS, AND EXAMPLE OF EXPOSURE ESTIMATE CALCULATIONS

This appendix summarizes packaging data recommended by FDA for evaluating exposure to FCS. An example of how these data are combined with levels of an FCS in food also is presented. A more complete discussion of the source of these data and their use in exposure calculations is presented in Section II.E.

TABLE I - CONSUMPTION FACTORS (CF)

	Package Category	CF	Package Category	CF
	Glass	0.1	Adhesives	0.14

A. General	Metal- Polymer coated	0.17	Retort pouch	0.0004
	Metal- Uncoated	0.03	Microwave susceptor	0.001
	Paper- Polymer coated	0.2	All Polymers[a]	0.8
	Paper- Uncoated and clay-coated	0.1	Polymer	0.4
B. Polymer	Polyolefins	0.35[b]	PVC	0.1
	-LDPE	0.12	-rigid/semirigid	0.05
	-LLDPE	0.06	-plasticized	0.05
	-HDPE	0.13	PET[c,d]	0.16
	-PP	0.04	Other Polyesters	0.05
	Polystyrene	0.14	Nylon	0.02
	EVA	0.02	Acrylics, phenolics, *etc.*	0.15
	Cellophane	0.01	All Others[e]	0.05

[a]Originates from adding CFs for metal-polymer coated, paper-polymer coated, and polymer (0.17 + 0.2 + 0.4 = 0.8).

[b]Polyolefin films, 0.17 (HDPE films, 0.006; LDPE films, 0.065; LLDPE films, 0.060; and PP films, 0.037).

[c]PET-coated board, 0.013; thermoformed PET, 0.0071; PET carbonated soft drink bottles, 0.082; custom PET, 0.056; crystalline PET, 0.0023; PET films, 0.03.

[d]A CF of 0.05 is used for recycled PET applications (see the document entitled "Points to Consider for the Use of Recycled Plastics in Food Packaging: Chemistry Considerations").

[e]As discussed in the text, a minimum CF of 0.05 will be used initially for all exposure estimates.

TABLE II - FOOD-TYPE DISTRIBUTION FACTORS (f_T)

	Package Category	Food-Type Distribution (f_T)			
		Aqueous[a]	Acidic[a]	Alcoholic	Fatty
A. General	Glass	0.08	0.36	0.47	0.09
	Metal- Polymer coated	0.16	0.35	0.40	0.09
	Metal- Uncoated	0.54	0.25	0.01[b]	0.20
	Paper- Polymer coated	0.55	0.04	0.01[b]	0.40
	Paper-.Uncoated and clay-coated	0.57	0.01[b]	0.01[b]	0.41
	Polymer	0.49	0.16	0.01[b]	0.34
B. Polymer	Polyolefins	0.67	0.01[b]	0.01[b]	0.31
	Polystyrene	0.67	0.01[b]	0.01[b]	0.31
	-impact	0.85	0.01[b]	0.04	0.10
	-nonimpact	0.51	0.01	0.01	0.47
	Acrylics, phenolics, *etc.*	0.17	0.40	0.31	0.12
	PVC	0.01[b]	0.23	0.27	0.49
	Polyacrylonitrile, ionomers, PVDC	0.01[b]	0.01[b]	0.01[b]	0.97
	Polycarbonates	0.97	0.01[b]	0.01[b]	0.01[b]
	Polyesters	0.01[b]	0.97	0.01[b]	0.01[b]
	Polyamides (nylons)	0.10	0.10	0.05	0.75
	EVA	0.30	0.28	0.28	0.14
	Wax	0.47	0.01[b]	0.01[b]	0.51
	Cellophane	0.05	0.01[b]	0.01[b]	0.93

[a]For 10% ethanol as the food simulant for aqueous and acidic foods, the food-type distribution factors should be summed.

[b]1% or less

Examples of Exposure Estimate Calculations

The following hypothetical examples are intended to illustrate the calculation of the concentration of an FCS in the daily diet (CF x <M>, *i.e.*, the fraction of food in the diet contacting the food-contact article times the average concentration of the FCS in food) and its EDI and CEDI.

Example 1

An FCN is received that describes the use of a new antioxidant at a maximum level of 0.25% w/w in polyolefins contacting food at or below room temperature (see Appendix II. Sections 1.E. through 1.G.). Migration values from LDPE reported to FDA for the three food simulants are given below:

Solvent (i)	M_i (mg/kg)
10% aqueous ethanol	0.060
50% aqueous ethanol	0.092
Miglyol 812	7.7

The notifier used a solvent volume-to-exposed surface area ratio of 10 mL/in^2. Therefore, solution concentrations are essentially equivalent to food concentrations (under the assumption that 10 g food contacts 1 in^2 of surface area). The CF and f_{TS} for polyolefins are given in Tables I and II, respectively. The <M> for the antioxidant would be calculated as follows:

$$\begin{aligned} \langle M \rangle &= (f_{aqueous}+f_{acidic})(M_{10\%\ ethanol}) + f_{alcohol}(M_{50\%\ ethanol}) + f_{fatty}(M_{Miglyol\ 812}) \\ &= (0.68)(0.060\ mg/kg)+0.01(0.092\ mg/kg)+0.31(7.7\ mg/kg) \\ &= 2.4\ mg/kg \end{aligned}$$

The concentration of the antioxidant in the daily diet resulting from the proposed use would be:

$$\begin{aligned} CF \times \langle M \rangle &= 0.35 \times 2.4\ mg/kg \\ &= 0.84\ mg/kg \end{aligned}$$

If there were no other permitted uses, then the CEDI would be calculated using the above value:

$$\begin{aligned} CEDI &= 3\ kg\ food/person/day \times 0.84\ mg\ antioxidant/kg\ food \\ &= 2.5\ mg/person/day \end{aligned}$$

Example 2

In a subsequent notification, expanded use of the same antioxidant in polycarbonate and polystyrene food contact articles is described. Each polymer would contact food at or below room temperature. Migration levels are given below:

Solvent	Migration to Food (mg/kg)		
	Polycarbonate	Polystyrene	Impact Polystyrene
10% aq. Ethanol	0.020	0.020	0.020
50% aq. Ethanol	0.025	0.035	0.22
Miglyol 812	0.033	0.15	6.2

The concentration of the antioxidant in the daily diet resulting from each of the proposed uses is calculated below. A CF of 0.04 for impact polystyrene and a CF of 0.06 for all other polystyrenes was used in the calculation.

Polycarbonates

$$\begin{aligned} CF \times \langle M \rangle &= 0.05(0.98(0.020\ mg/kg) +0.01(0.025\ mg/kg)+0.01(0.033\ mg/kg)) \\ &= 0.001\ mg/kg \end{aligned}$$

Polystyrene

$$\begin{aligned} CF \times \langle M \rangle &= 0.06(0.52(0.020\ mg/kg) +0.01(0.035\ mg/kg)+0.47(0.15\ mg/kg)) \\ &= 0.0049\ mg/kg \end{aligned}$$

Impact Polystyrene

$$\begin{aligned} CF \times \langle M \rangle &= 0.04(0.86(0.020\ mg/kg) +0.04(0.22\ mg/kg)+0.10(6.2\ mg/kg)) \\ &= 0.026\ mg/kg \end{aligned}$$

The total concentration of the antioxidant in the daily diet resulting from the additional uses in polycarbonate and polystyrene is approximately 0.032 mg/kg.

The contribution to the EDI is:

$$\begin{aligned} EDI &= 3\ kg\ food/person/day \times 0.032\ mg\ antioxidant/kg\ food \\ &= 0.096\ mg/person/day \end{aligned}$$

The CEDI for the previously permitted use (Example 1, EDI of 2.5 mg/person/day) and the additional proposed uses (EDI of 0.1 mg/person/day) would be 2.6 mg/person/day.

APPENDIX V. FOOD TYPES AND CONDITIONS OF USE

TABLE 1. TYPES OF RAW AND PROCESSED FOODS

I. Nonacid, aqueous products; may contain salt or sugar or both (pH above 5.0)
II. Acid, aqueous products; may contain salt or sugar or both, and including oil-in-water emulsions of low- or high-fat content.
III. Aqueous, acid or nonacid products containing free oil or fat; may contain salt, and including water-in-oil emulsions of low- or high-fat content.
IV. Dairy products and modifications: A. Water-in-oil emuslsions, high- or low-fat B. Oil-in-water emulsions, high- or low-fat
V. Low-moisture fats and oils
VI. Beverages: A. Containing up to 8 percent of alcohol. B. Nonalcoholic. C. Containing more than 8 percent alcohol.
VII. Bakery products other than those included under Types VIII or IX of this table: A. Moist bakery products with surface containing free fat or oil. B. Moist bakery products with surface containing no free fat or oil.
VIII. Dry solids with the surface containing no free fat or oil (no end test required).
IX. Dry solids with the surface containing free fat or oil.

TABLE 2. CONDITIONS OF USE

A. High temperature, heat sterilized or retorted (ca. 121 °C (250 °F)).
B. Boiling water sterilized.
C. Hot filled or pasteurized above 66 °C (150 °F).
D. Hot filled or pasteurized below 66 °C (150 °F).
E. Room temperature filled and stored (no thermal treatment in the container).
F. Refrigerated storage (no thermal treatment in the container).
G. Frozen storage (no thermal treatment in the container).
H. Frozen or refrigerated storage; ready prepared foods intended to be reheated in container at time of use.
I. Irradiation (ionizing radiation).
J. Cooking at temperatures exceeding 121 °C (250 °F).

APPENDIX VI. REFERENCES AND FOOTNOTES

1. REFERENCES

a. General References

American Society for Testing and Materials (ASTM), E 1303-95, Standard Practices for Refractive Index Detectors used in Liquid Chromatography. ASTM, West Conshohocken, PA 19428-2959.

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The following are lists of references that contain descriptions, photos, or drawings of migration cells for conducting migration testing for different packaging applications.

b. Cells for Migration Testing

Conventional Applications

ASTM F34-98, Standard Practice for Construction of Test Cell for Liquid Extraction of Barrier Materials. ASTM, West Conshohocken, PA 19428-2959.

Dow Chemical, Inc., A single-sided migration cell, known as the Dow cell, has been used with food oil at 175°C. The cell is available from: Kayeness, Inc., 115 Thousand Oaks Blvd., Suite 101, P.O. Box 709, Morgantown, PA 19543 (610-286-7555). Model no. D9030.

Figge, K. and Koch, J., **1973**, Effect of some variables on the migration of additives from plastics into edible fats. *Food Cosmetics Toxicology*, **11**, 975-988. The cell used was a single-sided cell in contact with food oil at 80°C.

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Limm, W. and Hollifield, H., **1995**. The cell used was a single-sided glass cell with water, food oil, and food at 135°C.

Snyder, R.C. and Breder, C.V., **1985**. The cell used was a double-sided (immersion) glass cell with water, 3% acetic acid, 95% ethanol, and oil at 40°C and 50% aqueous ethanol at 70°C. This cell is also specified i ASTM D4754-87 "Standard Test Method for the Two-Sided Liquid Extraction of Plastic Materials Using FDA Migration Cell." ASTM, West Conshohocken, PA 19428-2959.

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Microwave Applications

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Rijk, R. and De Kruijf, N., **1993**, Migration testing with olive oil in a microwave oven. *Food Additives and Contaminants*, **10** (6), 631-645.

2. FOOTNOTES

[1] This guidance has been prepared by the Office of Food Additive Safety in the Center for Food Safety and Applied Nutrition at the U.S. Food and Drug Administration.

[2] CAS Registry Numbers for new compounds and assistance with nomenclature can be obtained by writin to Chemical Abstracts Service (CAS) Client Services, 2540 Olentangy River Road, P.O. Box 3343, Columbus, OH 43210, or by visiting their website at http://www.cas.org/[3].

[3] Migration into food depends on the chemical structure of the FCS, the nature of the food matrix contacting the FCS, the type of food with which it is in contact, and the temperature and duration of food contact. Prior to the submission of an FCN or FAP, a potential submitter may wish to meet or correspond with FDA to discuss appropriate migration testing protocols (see Appendix II.).

[4] Migration values often are expressed in units of mg/dm^2. The mixed unit, mg/in^2, is preferred, however to facilitate conversion to concentrations in food. If 10 g of food are in contact with 1 square inch of food-contact surface, a migration of 0.010 mg/in^2 corresponds to a concentration in food of 1 mg/kg.

[5] In the past, FDA recommended 8% ethanol as an aqueous food simulant. Increasing the ethanol concentration from 8% to 10% will have a minimal impact on migration studies conducted on adjuvant/polymer systems. This change also harmonizes more closely FDA's migration protocols with those of other nations. See the reference list at the end of Appendix II. relating to FDA's development of the use of food simulants.

[6] Miglyol 812, a product of SASOL, GMbH, Witten, Germany.

[7] HB307 is available from NATEC, Behringstrasse 154, Postfach 501568, 2000 Hamburg 50, Germany.

[8] Previous test protocols (prior to 1995) recommended a test temperature of 49°C for 10 days. Recent studies by FDA, however, have shown little difference in migration levels at 49°C and 40°C (104°F). Furthermore, the differences in migration levels between 49°C and 40°C are of even less significance for migration studies requiring elevated temperatures (*e.g.*, 100°C or 121°C) for the first two hours. Up to 80% of the total migration observed over the 10 day period is usually completed within this two hour period at the higher temperature. Therefore, 40°C is acceptable for migration studies for room-temperature applications and for the portion of the migration test for elevated-temperature applications intended to reflect long term ambient storage.

[9] Chloroform may not be a good solvent for certain polymer/migrant systems. This is most likely due to a large difference in solubility between the polymer/migrants and chloroform. If the Hildebrand solubility parameter difference between the extractives and the solvent falls outside the range of ±3 (SI), one shoul either use another solvent that is capable of effectively solvating the potential extractives or demonstrate that the intended extractives are soluble in the chosen solvent. Hildebrand solubility parameters for

polymer/solvent systems can be found in the Polymer Handbook, 4th Edition, J. Brandrup (Editor), Edmund H. Immergut (Editor), Eric A. Grulke, Akihiro Abe, Daniel R. Bloch, John Wiley & Sons.

[10] The LOD is the lowest concentration of analyte that the analytical method can reliably detect above a blank (or control). It is preferable that the LOD be determined from analyses of five blank samples. The blank signal (*i.e.*, the analyte response for the blank sample or the width of the baseline close to the actua or expected analyte peak) is measured, and the average signal and standard deviation for the blank are calculated. The signal corresponding to the LOD is located three standard deviations above the average blank signal. The blank signal for the LOD is usually determined from the peak-to-peak noise measured on the baseline close to the actual or expected analyte signal. See American Society for Testing and Materials (ASTM), E 1303-95 or ASTM E 1511-95.

The region for quantitation of the analyte should clearly be above the LOD. The signal corresponding to the LOQ is located ten standard deviations above the average blank signal. See (Currie, **1968**) and (Keith., et al, **1980**).

† Temporarily unavailable on the web site.

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Links on this page:

1. http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/FoodIngredientsandPackaging/ucm081825.htm
2. http://www.access.gpo.gov/nara/cfr/index.html
3. http://www.cas.org/

附件 B　歐盟 PFOS 限制指令(2006/122/ECOF)

DIRECTIVE 2006/122/ECOF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 12 December 2006

amending for the 30th time Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (perfluorooctane sulfonates)

(Text with EEA relevance)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 95 thereof,

Having regard to the proposal from the Commission,

Having regard to the Opinion of the European Economic and Social Committee [1],

Acting in accordance with the procedure laid down in Article 251 of the Treaty [2],

Whereas:

(1) An OECD (Organisation for Economic Cooperation and Development) hazard assessment has been done on the basis of information that was available by July 2002. This assessment concluded that perfluorooctane sulfonates (hereinafter 'PFOS') are persistent, bioaccumulative and toxic to mammalian species and, therefore, indicate cause for concern.

(2) The risks posed to health and environment by PFOS have been assessed in accordance with the principles of Council Regulation (EEC) No 793/93 of 23 March 1993 on the evaluation and control of the risks of existing substances [3]. The risk assessment identified a need to reduce the risks to health and the environment.

(3) The Scientific Committee on Health and Environmental Risks (hereinafter 'SCHER') has been consulted. SCHER concluded that PFOS fulfil the criteria for classification as very persistent, very bioaccumulative and toxic. PFOS also have a potential for long range environmental transport and have the potential to produce adverse effects and therefore fulfil the criteria for being considered as persistent organic pollutants (POPs) under the Stockholm Convention [4]. SCHER identified a need for further scientific risk assessment of PFOS but it also agreed that risk reduction measures might be necessary to avoid the re-occurrence of former uses. According to SCHER, on-going critical uses in the aviation industry, the semiconductor industry and the photographic industry do not appear to pose a relevant risk to the environment or human health, if releases into the environment and workplace exposure are minimised. With regard to fire-fighting foams, SCHER agrees that health and environmental risks of substitutes should be assessed before a final decision can be taken. SCHER also agrees with restricting the use of PFOS in the plating industry, if there are no other measures available that could be applied to reduce the emissions during metal plating to a significantly lower level.

(4) In order to protect health and the environment, it therefore appears necessary that the placing on the market and the use of PFOS should be restricted. This Directive is intended to cover the major part of the exposure risks. Other minor uses of PFOS do not seem to pose a risk and they are therefore currently exempted. However, special attention should be given to plating processes using PFOS and therefore the releases from those processes need to be minimised by applying the best available techniques (hereinafter 'BAT') fully taking into account all relevant information contained in the BAT reference document on Surface Treatment of Metals and Plastics as developed for use under Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control [5] (IPPC Directive). In addition, Member States should establish inventories of those uses in order to acquire information about the actual quantities used and released.

(5) The semi-finished products and articles containing PFOS should also be restricted in order to protect the environment. The restriction should cover all the products and articles to which PFOS are intentionally added, taking into account that PFOS may have been used only in some distinct parts or in coatings of certain products and articles, such as textiles. This Directive should only restrict new products and should not apply to products already in use or on the second hand market. However, existing stocks of fire-fighting foams containing PFOS should be identified and their use should be allowed to continue only for a limited time to prevent possible further emissions from the use of such products.

[1] OJ C 195, 18.8.2006, p. 10.

[2] Opinion of the European Parliament of 25 October 2006 (not yet published in the Official Journal) and Council Decision of 11 December 2006.

[3] OJ L 84, 5.4.1993, p. 1. Regulation as amended by Regulation (EC) No 1882/2003 of the European Parliament and of the Council (OJ L 284, 31.10.2003, p. 1).

[4] Council Decision 2006/507/EC of 14 October 2004 concerning the conclusion, on behalf of the European Community, of the Stockholm Convention on Persistent Organic Pollutants (OJ L 209, 31.7.2006, p. 1).

[5] OJ L 257, 10.10.1996, p. 26. Directive as last amended by Regulation (EC) No 166/2006 of the European Parliament and of the Council (OJ L 33, 4.2.2006, p. 1).

(6) To ensure ultimately the phase-out of uses of PFOS the Commission should review each derogation under this Directive when new information on the uses and safer alternatives developed gives grounds for it. The derogation should only be allowed to continue for essential uses on the condition that safer substances or technologies, that are technically and economically feasible, do not exist and BAT are applied to minimise emissions of PFOS.

(7) Perfluorooctanoic acid (PFOA) and its salts are suspected to have a similar risk profile to PFOS, and consequently there is a need to keep under review the ongoing risk assessment activities and the availability of safer alternatives and to define what kind of risk reduction measures, including restrictions on marketing and use, if appropriate, should be applied within the European Union.

(8) Directive 76/769/EEC [1] should be amended accordingly.

(9) The objective of this Directive is to introduce harmonised provisions with regard to PFOS, thus preserving the internal market whilst ensuring a high level of protection of human health and the environment, as required by Article 95 of the Treaty.

(10) This Directive is without prejudice to the Community legislation laying down minimum requirements for the protection of workers, such as Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work [2], and individual directives based thereon, in particular Directive 2004/37/EC of the European Parliament and of the Council of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (Sixth individual Directive within the meaning of Article 16(1) of Council Directive 89/391/EEC) (codified version) [3] and Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) [4],

HAVE ADOPTED THIS DIRECTIVE:

Article 1

Annex I to Directive 76/769/EEC is hereby amended as set out in the Annex to this Directive.

Article 2

1. Member States shall adopt and publish, not later than 27 December 2007, the laws, regulations and administrative provisions necessary to comply with this Directive. They shall forthwith communicate to the Commission the text of those measures and a table showing the correlation between those measures and this Directive.

They shall apply these measures from 27 June 2008.

When Member States adopt these measures, they shall contain a reference to this Directive or shall be accompanied by such reference on the occasion of their official publication. The methods of making such reference shall be laid down by the Member States.

2. Member States shall communicate to the Commission the text of the main provisions of national law which they adopt in the field covered by this Directive.

Article 3

This Directive shall enter into force on the day of its publication in the *Official Journal of the European Union*.

Article 4

This Directive is addressed to the Member States.

Done at Strasbourg, 12 December 2006.

For the European Parliament	*For the Council*
The President	*The President*
J. BORRELL FONTELLES	M. PEKKARINEN

[1] OJ L 262, 27.9.1976, p. 201. Directive as last amended by Directive 2005/90/EC of the European Parliament and of the Council (OJ L 33, 4.2.2006, p. 28).

[2] OJ L 183, 29.6.1989, p. 1. Directive as amended by Regulation (EC) No 1882/2003.

[3] OJ L 158, 30.4.2004, p. 50. Corrigendum in OJ L 229, 29.6.2004, p. 23.

[4] OJ L 131, 5.5.1998, p. 11. Directive as amended by the 2003 Act of Accession.

ANNEX

The following point is added to Annex I to Directive 76/769/EEC:

'52. Perfluorooctane sulfonates (PFOS) $C_8F_{17}SO_2X$ (X = OH, Metal salt (O-M+), halide, amide, and other derivatives including polymers)	(1) May not be placed on the market or used as a substance or constituent of preparations in a concentration equal to or higher than 0,005 % by mass. (2) May not be placed on the market in semi-finished products or articles, or parts thereof, if the concentration of PFOS is equal to or higher than 0,1 % by mass calculated with reference to the mass of structurally or microstructurally distinct parts that contain PFOS or, for textiles or other coated materials, if the amount of PFOS is equal to or higher than 1 $\mu g/m^2$ of the coated material. (3) By way of derogation, paragraphs 1 and 2 shall not apply to the following items, nor to substances and preparations needed to produce them: (a) photoresists or anti reflective coatings for photolithography processes, (b) photographic coatings applied to films, papers, or printing plates, (c) mist suppressants for non-decorative hard chromium (VI) plating and wetting agents for use in controlled electroplating systems where the amount of PFOS released into the environment is minimised, by fully applying relevant best available techniques developed within the framework of Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (*), (d) hydraulic fluids for aviation. (4) By way of derogation from paragraph 1, fire-fighting foams that have been placed on the market before 27 December 2006 can be used until 27 June 2011. (5) Paragraphs 1 and 2 shall apply without prejudice to Regulation (EC) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents (**). (6) Not later than 27 December 2008 Member States shall establish and communicate to the Commission an inventory that covers: (a) processes that are subject to derogation in paragraph 3(c) and the amounts of PFOS used in and released from them, (b) existing stocks of fire-fighting foams containing PFOS. (7) As soon as new information on details of uses and safer alternative substances or technologies for the uses becomes available, the Commission shall review each of the derogations in paragraph 3(a) to (d) so that: (a) the uses of PFOS will be phased out as soon as the use of safer alternatives is technically and economically feasible, (b) a derogation can only be continued for essential uses for which safer alternatives do not exist and where the efforts undertaken to find safer alternatives have been reported on, (c) releases of PFOS into the environment have been minimised, by applying best available techniques. (8) The Commission shall keep under review the ongoing risk assessment activities and the availability of safer alternative substances or technologies related to the uses of perfluorooctanoic acid (PFOA) and related substances and propose all necessary measures to reduce identified risks, including restrictions on marketing and use, in particular when safer alternative substances or technologies, that are technically and economically feasible, are available.'

(*) OJ L 257, 10.10.1996, p. 26. Directive as last amended by Regulation (EC) No 166/2006 of the European Parliament and of the Council (OJ L 33, 4.2.2006, p. 1).
(**) OJ L 104, 8.4.2004, p. 1. Regulation as amended by Commission Regulation (EC) No 907/2006 (OJ L 168, 21.6.2006, p. 5).

附件 C　PFOA 遷移試驗方法初稿

行政院衛生署食品藥物管理局

不沾塗層鍋具及防油紙之全氟辛酸(PFOA)遷移試驗方法 (初稿)

99.12.07

方法概要

在盛裝、包裝、輸送或烹調食品的過程中，可能會將食品接觸物件(Food contact article)中之食品接觸物質(Food contact substance, FCS)遷移至食品中，造成民眾攝食的健康風險。為評估其遷移量(Migration concentration, MC)，參考美國食品藥物管理局食品安全及應用營養中心(USFDA, 2007)及歐盟(EU, 2004)之FCS 遷移試驗一般性指引，及我國塑膠類之食品器具、容器；包裝檢驗方法(食品藥物管理局，93 年)，訂定不沾鍋及防油紙全氟辛酸(Perfluorooctanoic acid, PFOA)之室溫及高溫模擬調理之遷移試驗方法，室溫遷移試驗條件參考 USEPA (2009)，高溫模擬調理遷移試驗條件參考 Begley et al. (2005, 2008)及 Bononi and Tateo (2007)。不沾鍋採盛裝法，試驗結果以 ng/cm^2 表示，防油紙採全浸泡法(Total immersion)，試驗結果以 ng/g 表示，亦可以防油紙之面積密度(g/cm^2)，將單位轉換為 ng/cm^2 (註 1)。遷移方法流程如圖一及圖二所示。

1. 適用範圍：本遷移試驗方法適用於不沾塗層鍋具及食品包裝防油紙中全氟辛酸遷移溶出之試驗。
2. 遷移試驗方法：
   2.1. 不沾塗層鍋具：
      2.1.1. 不沾鍋物件採集與保存：
         2.1.1.1. 一般而言，試驗目的為查核市售物件是否達到製造的品管要求，如 GMP，可自賣場採集包裝完好無瑕疵之不沾鍋物件。但若試驗目的為查核重複使用的物件，則應依實際需求採集烹調使用過的物件。
         2.1.1.2. 拆除包裝後，使用三層鋁箔包覆不沾鍋，再放置於聚丙烯(PP)密封袋中，標示樣品編號後，放置於室溫中保存。
         2.1.1.3. 維持不沾鍋之密封狀態直至進行遷移試驗前。
      2.1.2. 裝置：

2.1.2.1. 離心機。

2.1.2.2. 震盪機。

2.1.2.3. 氮氣蒸發裝置(Nitrogen evaporator)。

2.1.3. 試藥：

2.1.3.1. HPLC-級甲醇。

2.1.3.2. 不含 PFOA 之清潔劑。

2.1.3.3. 去離子水。

2.1.3.4. 回收查核擬似標準品(Recovery check surrogate standard, RCSS)(註 2)。

2.1.4. 器具及材料：

2.1.4.1. 鋁箔紙。

2.1.4.2. 離心管：170 mL，具旋轉蓋(非 Teflon 墊片)聚乙烯(PE)材質。

2.1.4.3. 萃出溶劑層收集瓶：170 mL，聚丙烯(PP)材質。

2.1.5. 不沾鍋遷移溶出液之製備：

2.1.5.1. 室溫遷移：拆除包覆不沾鍋之三層鋁箔，以不含 PFOA 之清潔劑清洗不沾鍋後，再以去離子水沖洗數次，以乾淨毛巾拭乾。精確量取 100-150 mL HPLC-級甲醇倒入不沾鍋中，使其覆蓋鍋底深度約為 0.3 cm，使用鋁箔包覆不沾鍋頂部，其邊緣需密實壓緊至厚度約 0.5 cm，如圖三所示，靜置室溫下連續萃取 24 小時，萃取過程不時緩和搖晃，但不可將盛裝之溶媒傾洩或與鍋具其它非萃取部位接觸。萃取完成後精確量取預期溶出濃度之 0.5-2 倍的回收查核擬似標準品 (Recovery check surrogate standard, RCSS) (註 2)加入鍋具中與萃出液充分混合，將混和液收集於 170 mL 之具旋轉蓋(非 Teflon 墊片)聚乙烯(PE)離心管中，將離心管於 4500 rpm 離心機中迴轉 5 min，將離心後萃出溶劑層收集於 170 mL 之聚丙烯(PP)管，吹氮濃縮至約 1 mL，最後定容為 10 mL 上機。

2.1.5.2. 高溫模擬調理遷移：拆除包覆不沾鍋之三層鋁箔，以不含 PFOA 之清潔劑清洗不沾鍋後，以去離子水沖洗數次，再以乾淨毛巾拭乾。將食用油(註 3)置於另一不鏽鋼盤預熱至 125±5°C，量取

20 mL 預熱之食用油倒入遷移實驗鍋具中，維持 125±5°C 10 min (Bononi and Tateo, 2007)，萃取完成後，將食用油倒入不鏽鋼杯冷卻後置於 50 mL PP 離心管並秤重，量取 PFOA -13C4 0.5 μg/mL 0.1 mL 回收查核擬似標準品(Recovery check surrogate standard, RCSS) (註 2) 加入離心管中與食用油充分混合後，加入 25 mL H2O:MeOH=20:80 振盪萃取 30 min，最後進行 4600 rpm 離心 5 min 後取萃出溶劑層置於 15 mL PP 離心管，吹氮濃縮至 2 mL，最後定容至 10 mL 後上機。

2.2. 防油紙：

2.2.1. 防油紙物件採樣及保存：

2.2.1.1. 調查及採集市面上於處理、製造過程中含有全氟化物之防油紙物件。

2.2.1.2. 使用三層鋁箔以及 PP 密封袋將其完全包覆，標示樣品編號後，放置於室溫中妥為保存。

2.2.1.3. 維持防油紙之密封狀態直至進行遷移試驗前。

2.2.2. 裝置：

2.2.2.1. 乾燥器。

2.2.2.2. 電子天秤。

2.2.2.3. 變速三維圓周旋轉搖床(Nutating mixer)。

2.2.2.4. 離心機。

2.2.2.5. 氮氣蒸發裝置(Nitrogen evaporator)。

2.2.3. 試藥：

2.2.3.1. HPLC-級甲醇。

2.2.3.2. 回收查核擬似標準品(Recovery check surrogate standard, RCSS)(註 2)。

2.2.3.3. 食用油(註 3)。

2.2.4. 器具及材料：

2.2.4.1. 鋁箔紙。

2.2.4.2. 鋼刀。

2.2.4.3. 離心管：50 mL，具旋轉蓋(非 Teflon 墊片)聚乙烯(PE)材質。

2.2.4.4. 萃出溶劑層收集瓶：170 mL，聚丙烯(PP)材質。

2.2.5. 防油紙遷移溶出液之製備：

2.2.5.1. 室溫遷移：拆除包覆防油紙之三層鋁箔，使用鋼刀將防油紙切成片狀(註 4)，大小約 1 g 重量，於乾燥器中放置八小時以上，自乾燥器中移出片狀樣品，精秤並記錄秤重，確保樣品約為 1 g 重。精確量取 45 mL HPLC-級之甲醇加入 50 mL 聚乙烯(PE)離心管中，將片狀樣品置入該(PE)離心管中開始萃取，使用變速三維圓周旋轉搖 (Nutating mixer) 室溫萃取 24 小時，萃取完成後，精確量取 50 μL 之回收查核擬似標準品(Recovery check surrogate standard, RCSS) (註 2)，加至該離心管中，將萃取完成之 PE 離心管於 4500 rmp 離心機中迴轉 5 min，將離心後萃出溶劑層收集於 170 mL 之聚丙烯(PP)管，吹氮濃縮至約 1 mL，最後定容為 10 mL 上機。

2.2.5.2. 高溫模擬調理遷移：拆除包覆防油紙之三層鋁箔，使用鋼刀將防油紙切成片狀(註 4)，大小約 1 g 重量，於乾燥器中放置八小時以上，自乾燥器中移出片狀樣品，精秤並記錄秤重，確保樣品約為 1 g 重。取 20 mL 食用油(註 3)置於不鏽鋼盤預熱至 100±5°C，取 1g 防油紙平置於不鏽鋼盤盤面，溫度維持 100±5°C，15 min，提起防油紙稍瀝乾，食用油冷卻後置於 50 mL PP 離心管並秤重，量取 PFOA -$^{13}C_4$ 0.5 μg/mL 0.1 mL 回收查核擬似標準品(Recovery check surrogate standard, RCSS) (註 2)加入離心管中與食用油充分混合後，加入 25 mL H_2O:MeOH=20:80 振盪萃取 30 min，最後進行 4600 rpm 離心 5 min 後取萃出溶劑層置於 15 mL PP 離心管吹氮濃縮至 2 mL，最後定容為 10 mL 上機。

3. 結果計算：

3.1. 遷移濃度 (a) 單位若表示為 ng/L 時

$$a = \frac{c \times V}{2 \times S}$$

c：溶出濃度，ng/L

V：實際使用浸泡體積，mL

2：每平方公分面積所需之溶劑體積，mL/cm^2

S：試驗物件之單面面積，cm^2

3.2. 遷移濃度 (a_o)單位若表示為 ng/cm^2 時

$$a_o = \frac{c \times V}{A \times 1000}$$

c：溶出濃度，ng/L

V：實際使用浸泡體積，mL

A：試驗物件之單面面積，cm^2

1000：單位換算，1L=1000 mL

3.3. 遷移濃度 (a_I) 單位若表示為 ng/g 時

$$a_I = \frac{c \times V}{M}$$

c：溶出濃度，ng/L

V：實際使用浸泡體積，mL

M：試驗物件之質量，g

4. 品管要求：

4.1. PFOA 已廣泛使用於與 Teflon 有關之塑膠，試驗過程中，應查核各類可能的汙染，包括貯存容器包裝材料、蒸餾水、試劑、容器、管件、接頭、墊圈、溶媒、油品及調味料等。

4.2. 若監測目的為評估各種市售食品接觸物件之製造品質，採集每一型號物件各一件，分別進行遷移試驗後，再將溶出液分樣，重複分析之遷移濃度之相對差異百分比 (Relative percentage difference, RPD)應小於或等於 20%，其結果以平均值表示。$RPD=|X_1 - X_2|/(X_1 + X_2)/2$，其中 X_1 為 X_2 之重複樣品測值。

4.3. 若監測目的為業者自行送審所需之資料，應採集每一型號物件各三件，分別進行遷移試驗後，三重複之遷移試驗濃度之相對標準偏差 (Relative standard deviation, RSD) 參照 USFDA (2007)方法，若檢出食品或溶媒濃度＜0.1 mg/kg(155 ng/cm^2)，則應＜20%；若檢出濃度＞0.1 mg/kg，則應＜10%。

4.4. 所有遷移試驗之全程回收率查核擬似標準品 (Recovery check surrogate standard, RCSS) (註 2) 之回收率參照 USFDA (2007)方法，若檢出食品或溶媒濃度＜0.1 mg/kg，則應在 60-110%範圍內；若檢出濃度＞0.1 mg/kg，則回收率應為 80-110%範圍內。

4.5. 每一批次或每 10 個樣品應執行一個方法試劑空白 (Method reagent blank)。

參考文獻：

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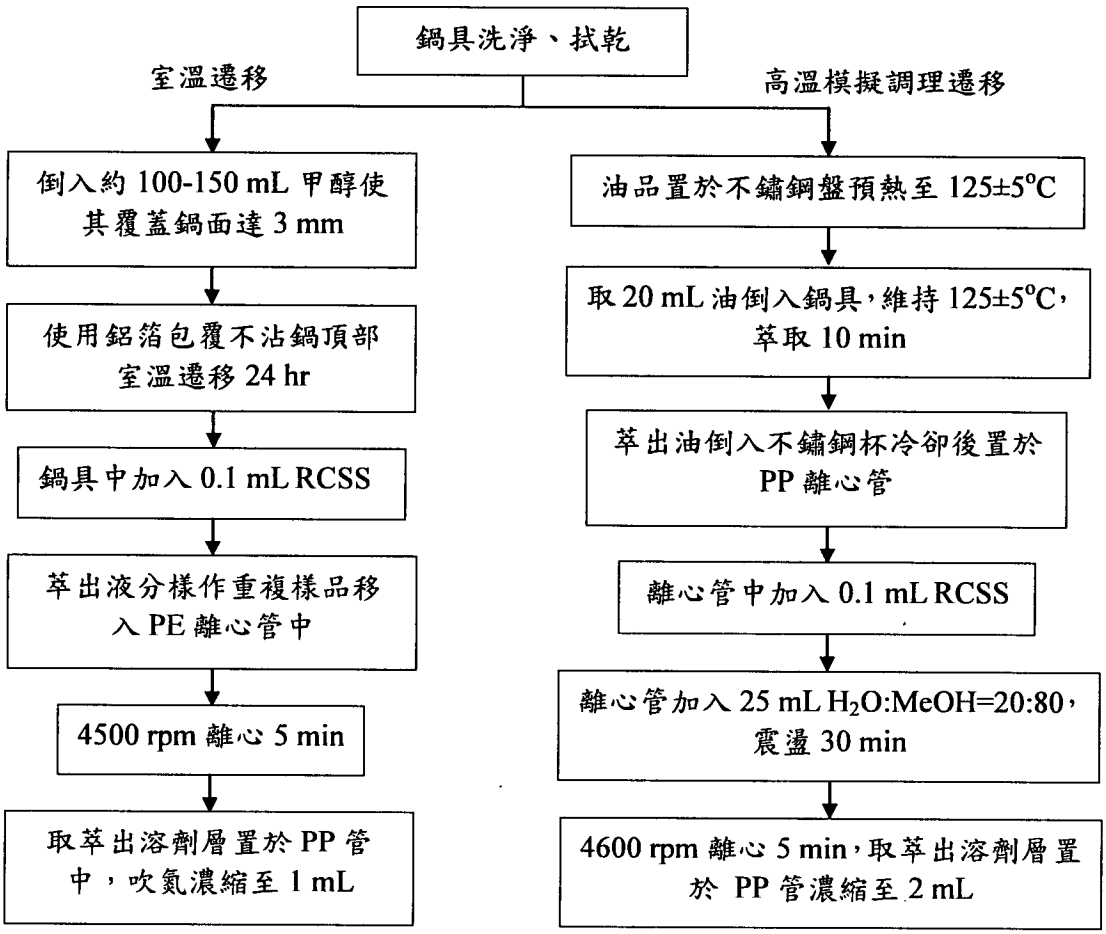
附註：

註 1：試驗結果遷移濃度單位之選用應視政府相關單位所訂定之特定遷移限值 (Specific migration limit, SML) 之單位而定。

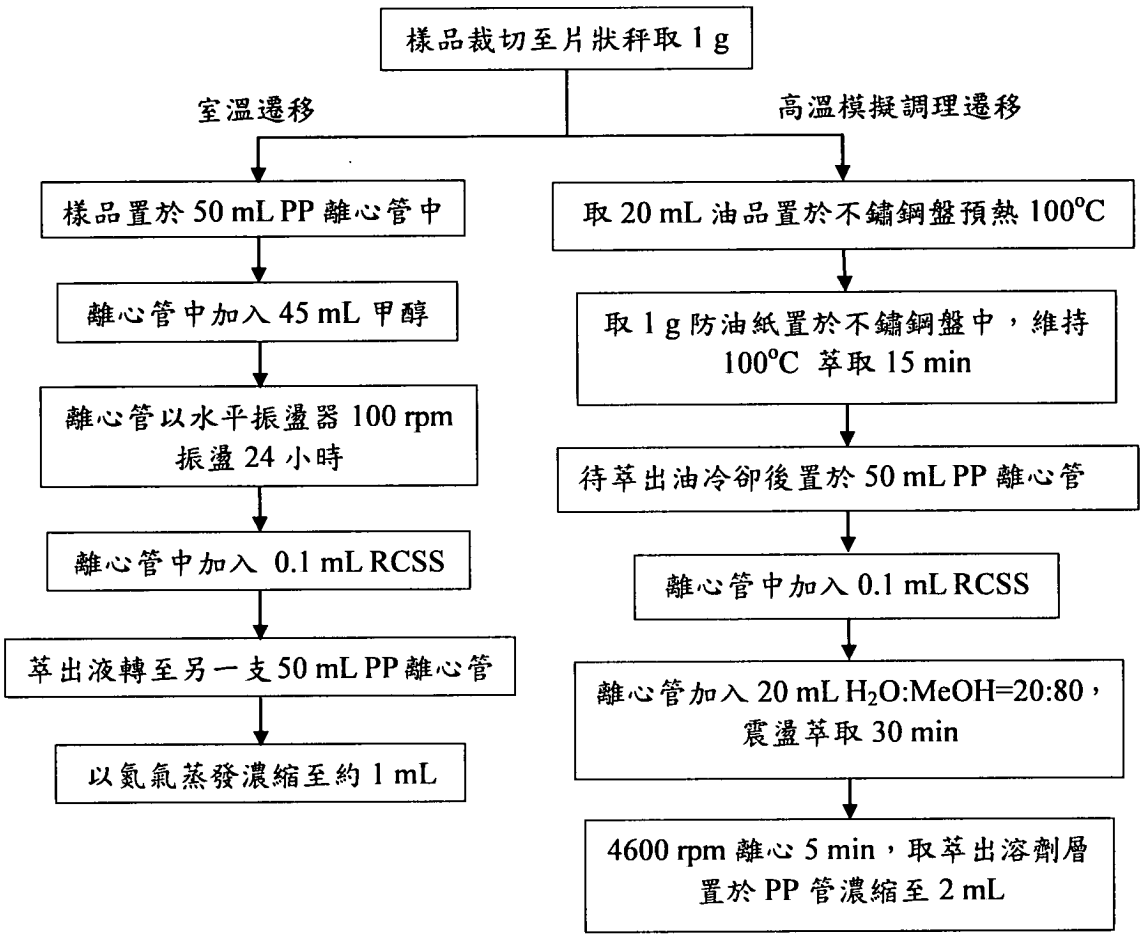
註 2：RCSS, 0.5μg/mL perfluoro-*n*-[1, 2-$^{13}C_2$] decanoic acid，此為擬似標準品 (Surrogate standard)，添加量約為預期樣品遷移量之 0.5-2 倍。

註 3：食用油可為市售大豆沙拉油、橄欖油，視實際模擬調理所需，亦可使用其他種類之油品或合成油。亦可於食用油中添加一定量的調味料，如食塩或醬油等，但應查核食用油及所有調味料是否含有 PFOA 之背景污染。

註 4：防油紙可裁取為 6 × 6 cm 或 10 × 10 cm，大小取決於防油紙之每單位面積之重量。



圖一 本研究研擬之不沾鍋 PFOA 遷移試驗方法流程圖



圖二 本研究研擬之食品包裝防油紙 PFOA 遷移試驗方法流程圖

圖三 鋁箔覆蓋不沾鍋頂部，邊緣密實厚需度達 0.5 cm

附件 D　PFOA 溶出檢測分析方法初稿

食品包裝及炊具溶出檢驗方法－全氟辛酸之檢驗 (初稿)

Method of Test for Leaching from Food Packaging and Cookware－ Test of Perfluorooctanoic acid

1. 適用範圍：本檢驗方法適用不沾塗層鍋具及食品包裝紙中全氟辛酸室溫甲醇溶出及高溫食用油模擬調理溶出之檢驗。
2. 檢驗方法：液相層析串聯質譜分析法(Liquid chromatography/tandem mass spectrometry, LC/MS/MS)，流程圖詳參圖一及二。

2.1. 裝置：

2.1.1. 液相層析串聯質譜分析儀：

2.1.1.1. 離子源：電灑離子化負離子 (Negative ion electrospray ionization, ESI-)。

2.1.1.2. 層析管：Agilent ZORBAX Eclipse XDB-C18 3.5μm 內徑 2.1 mm × 5 cm，或同級品。

2.1.2. 振盪機(Shaker)。

2.1.3. 氮氣蒸發裝置(Nitrogen evaporator)。

2.1.4. 旋渦混合器(Vortex mixer)。

2.1.5. 超音波震盪器(Sonicator)

2.2. 試藥：甲醇採用液相層析級；醋酸銨採用試藥特級；全氟辛酸(Perfluorooctanoic acid, PFOA)對照用標準品；全氟辛酸同位素(PFOA -$^{13}C_4$)回收查核擬似標準品(Recovery check surrogate standard, RCSS)；全氟癸酸同位素(PFDA -$^{13}C_2$)內部標準品(Internal standard, IS)。

2.3. 器具及材料：

2.3.1. 容量瓶：50 mL，聚丙烯(PP)材質。

2.3.2. 離心管：50 mL，聚丙烯(PP)材質。

2.3.3. 濾膜：孔徑 0.2 μm，Nylon材質。

2.3.4. 上機樣品瓶：1 mL，聚丙烯(PP)材質。

2.4. 試劑之調製：

2.4.1. 95%甲醇溶液：取95 mL甲醇加入5 mL去離子水。

2.4.2. 2 mM醋酸銨溶液：秤取醋酸銨0.154 g，以去離子水溶解成1000 mL。

2.5. 移動相溶液之配製：

2.5.1. 移動相溶液A：甲醇溶液以0.2 μm濾膜過濾，取濾液作移動相溶液A。

2.5.2. 移動相溶液B：稱取醋酸銨 0.154 g，以去離子水溶解使成1000 mL，以 0.2 μm濾膜過濾，取濾液作移動相溶液B。

2.6. 標準溶液之配製：

2.6.1. 回收查核擬似標準溶液：取全氟辛酸同位素(PFOA -$^{13}C_4$)回收查核擬似標準品(Recovery check surrogate standard, RCSS) 50 μg/mL 500 μL，以95%甲醇溶液定容至50 mL。

2.6.2. 內部標準溶液：取全氟癸酸同位素(PFDA -$^{13}C_2$)內部標準品(Internal standard, IS) 50 μg/mL 500 μL，以95%甲醇溶液定容至50 mL。

2.6.3. 標準溶液：取全氟辛酸(PFOA)對照用標準品50 mg，精確秤量，以95%甲醇溶液溶解並定容至50 mL，作為標準原液。臨用時取適量標準原液，以甲醇：2 mM 醋酸銨(1:5, v/v)溶液稀釋至濃度為0.2-10.0 ng/mL (ppb)，並於其中添加回收查核擬似標準溶液及內部標準溶液至濃度為5.0 ng/mL。

2.7. 檢液之調製：

2.7.1. 室溫甲醇溶出

2.7.1.1. 不沾塗層鍋具：依鍋具大小加入覆蓋鍋底面水平深度達0.3 cm之甲醇(約100 - 150 mL)，以鋁箔延鍋緣緊密包覆整個鍋具厚度約0.5 cm以防萃取溶劑揮發，於室溫水平放置24小時，收集萃出液，加入回收查核擬似標準溶液0.1 mL，平分為兩份分置於各別50 mL聚丙烯材質離心管並精秤各萃出液重量，以氮氣蒸發濃縮至低於1 mL，於各離心管中加入甲醇：2 mM 醋酸銨(1:5, v/v)溶液3 mL，以超音波及渦旋振盪器振盪，再將兩份萃出液收集至各別15 mL 聚丙烯材質離心管，將內部標準溶液依萃出

液分樣時秤重之重量比乘以0.1 mL所得之體積分別添入各樣品分液中，加入甲醇：2 mM 醋酸銨(1:5, v/v)溶液至10 mL標線，取0.5 mL經0.2 μm 濾膜過濾至聚丙烯材質上機樣品瓶，供作檢液。詳細之遷移試驗方法請參考「不沾塗層鍋具及防油紙之全氟辛酸遷移試驗方法」。

2.7.1.2. 食品包裝紙：樣品裁切至片狀約1 g，精確秤量，置於50 mL聚丙烯材質離心管中。再加入45 mL甲醇，以水平振盪器100 rpm來回振盪24小時，萃出液移入另一支50 mL聚丙烯材質離心管，加入回收查核擬似標準溶液0.1 mL，以氮氣蒸發濃縮至約1 mL，加入內部標準溶液0.1 mL，加入甲醇：2mM 醋酸銨(1:5, v/v)溶液至10 mL標線，以超音波及渦旋振盪器振盪，取0.5 mL經0.2 μm濾膜過濾至聚丙烯材質上機樣品瓶，供作檢液。詳細之遷移試驗方法請參考「不沾塗層鍋具及防油紙之全氟辛酸遷移試驗方法」。

2.7.2. 高溫食用油模擬調理溶出

2.7.2.1. 不沾塗層鍋具：食用油置於不銹鋼鍋中同溶出實驗鍋具先置於加熱板控溫至125±5 °C，取20 mL食用油放入鍋具中，將食用油平均接觸鍋底維持125±5 °C 10 min，倒入不鏽鋼杯冷卻後置於50 mL聚丙烯材質離心管並精秤食用油重量，加入回收查核擬似標準溶液0.1 mL及甲醇：去離子水(4:1, v/v)溶液25 mL振盪萃取30 min，以4600 rpm離心5 min後取萃出溶劑層，萃出液平分為兩份分置於兩個50 mL聚丙烯材質離心管並精秤各萃出液重量，以氮氣蒸發濃縮至約2 mL，將內部標準溶液依萃出液分樣時之萃出液重量比乘以0.1 mL所得之體積分別添入各分樣濃縮液中，加入甲醇：2mM 醋酸銨(1:5, v/v)溶液至10 mL標線，以超音波及渦旋振盪器振盪，取0.5 mL經0.2 μm濾膜過濾至聚丙烯材質上機樣品瓶，供作檢液。詳細之遷移試驗方法請參考「不沾塗層鍋具及防油紙之全氟辛酸遷移試驗方法」。

2.7.2.2. 食品包裝紙：取20mL食用油置於不鏽鋼盤預熱至100±5°C，秤取1 g包裝紙，以不沾塗層面平覆接觸食用油於不鏽鋼盤盤面維持100±5 °C 15 min，提起包裝紙稍瀝乾，食用油冷卻後置入50 mL聚丙烯材質離心管並精秤食用油重量，加入回收查核擬似標準溶液0.1 mL及甲醇：去離子水(4:1, v/v)溶液25 mL振盪萃取30 min，以4600 rpm離心5 min後取萃出溶劑層置於50 mL聚丙烯材質離心管，以氮氣蒸發濃縮至約2 mL，加入內部標準溶液0.1 mL，加入甲醇：2 mM 醋酸銨(1:5, v/v)溶液至10 mL標線，以超音波及渦漩振盪器振盪，取0.5 mL經0.2 μm濾膜過濾至聚丙烯材質上機樣品瓶，供作檢液。詳細之遷移試驗方法請參考「不沾塗層鍋具及防油紙之全氟辛酸遷移試驗方法」。

2.8. 檢量線(標準曲線)之製作：

依2.6.3節調製標準溶液，並參照下列條件進行液相層析串聯質譜分析，就全氟辛酸與內部標準品波峰面積比，與對應之全氟辛酸濃度，製作檢量線(標準曲線)。

液相層析串聯質譜分析測定條件：

移動相溶液：每個樣品分析皆以A液：B液為80：20(v/v)預先平衡3分鐘，再依以下列比例(v/v)混合作為移動相溶液，進行梯度分析。

時間(min)	A (%)	B (%)
0	80	20
0.5	50	50
5.5	5	95
8.0	5	95
8.1	80	20
10.0	80	20

取樣分析量：10 μL

移動相流速：0.3 mL/min。

離子噴灑電壓(IonSpray voltage)：-4.5 kV。

鑑別模式：多重反應偵測模式(Multiple reaction monitoring mode, MRM)。

鑑別離子、Declustering potential (DP)與碰撞能量(Collision energy, CE)如下表：

分析物	母離子(m/z)	子離子(m/z)	DP(V)	CE(eV)
全氟辛酸	413	369	-45	-14
		169	-45	-23
全氟辛酸同位素(PFOA-$^{13}C_4$)回收查核擬似標準品(RCSS)	417	372	-45	-14
全氟癸酸同位素(PFDA-$^{13}C_2$)內部標準品(IS)	515	470	-55	-14

全氟辛酸定量離子為369

2.9. 鑑別試驗及含量測定：

精確量取檢液及標準溶液各10 μL，分別注入液相層析串聯質譜儀中，參照2.8 節液相層析串聯質譜條件進行分析，各檢液及標準溶液皆執行三重複分析，就檢液與標準溶液所得波峰之滯留時間及多重反應偵測相對離子強度(註1)鑑別之，並依下列計算式求出檢體中各全氟辛酸之溶出量：

2.9.1. 常溫甲醇溶出

$$\text{樣品全氟辛酸溶出之濃度(ng/g(ppb)或ng/cm}^2\text{)} = \frac{A_{sample} \times V}{M}$$

A_{sample}：由三重複分析依檢量線(標準曲線)迴歸之全氟辛酸濃度(ng/mL)平均值，其檢量線(標準曲線)及樣品數值皆依IS波峰面積調整。

V：檢體最後定容之體積(mL)。

M：取樣分析檢體之重量或面積(g或cm^2)。

2.9.2. 高溫食用油模擬調理溶出

$$\text{溶出後食用油中全氟辛酸濃度(ng/mL(ppb))} = \frac{A_{sample} \times V}{M/D}$$

A_{sample}：由三重複分析依檢量線(標準曲線)迴歸之全氟辛酸濃度(ng/mL)平均值，其檢量線(標準曲線)及樣品數值皆依IS波峰面積調整。

V：檢體最後定容之體積(mL)。

M：溶出後食用油冷卻後置於離心管之油重量(g)。

D：食用油密度(g/mL)

3. 品質管制：

3.1. 檢量線(標準曲線)之線性迴歸係數 $r > 0.995$ 以上。

3.2. 10 個樣品為一批次，不足 10 個樣品時仍以一批次計。

3.3. 樣品分析之回收查核擬似標準品(Recovery check surrogate standard, RCSS)於室溫甲醇溶出及高溫食用油模擬調理溶出檢驗回收率範圍均為60-110%。

3.4. 各樣品皆執行重複樣品分析，確認結果的精密度，即為包裝紙各秤取 1 g 執行實驗，不沾塗層鍋具則為萃出液經分樣之步驟後，作為樣品及重複樣品；當樣品及重複樣品中含可定量之待測物時，其檢測值相對差異百分比(RPD)應在 20%內；若樣品及重複樣品中不含可定量之待測物時，其室溫及高溫分析及重複分析之回收查核擬似標準品(Recovery check surrogate standard, RCSS)測值之相對差異百分比應在 20%以內。

3.5. 檢量線(標準曲線)完成後執行檢量線確認(Initial calibration verification, ICV)，用不同於檢量線(標準曲線)來源之另一標準品或相同來源但不同批次標準品，配製檢量線(標準曲線)中間濃度 5 ng/mL，確認檢量線(標準曲線)之適用性，相對誤差範圍應在±15%內。

3.6. 每批次上機執行之品管樣品依序為：檢量線查核、方法空白樣品、查核標準品，及於樣品分析完後再執行一次檢量線查核；各品管樣品詳述如下：

2.1 檢量線查核(Continuing calibration verification, CCV)：以檢量線(標準曲線)中間濃度 5 ng/mL，確認分析過程是否須重新製作檢量線(標準曲線)，每批次於樣品分析前及樣品分析完成後各分析一次，以確認分析前後之品質，相對誤差範圍應在 ±15% 內。

2.2 方法空白樣品(Method blank, BK)：室溫甲醇溶出檢驗為溶劑未經萃取步驟，直接執行前處理後上機，高溫食用油模擬調理溶出檢驗為食用油未經高溫溶出步驟即執行前處理後上機，用以監測分析過程中是否遭受污染，線性迴歸值應小於 1/2 倍之檢量線(標準曲線)最低點 0.2 ng/mL。

2.3 查核標準品(Check standard)：用不同於檢量線(標準曲線)來源之另一標準品或相同來源但不同批次標準品，室溫甲醇溶出檢驗為添加入

未經萃取步驟之溶劑，高溫食用油模擬調理溶出檢驗為添加入未經高溫溶出步驟之食用油，添加量為相當於分析時自檢量線(標準曲線)對應後所得之濃度 2 ng/mL，執行前處理及上機檢測，確認分析結果之準確度或品質，室溫及高溫溶出檢驗查核標準品回收率範圍應在 60-110% 內。

3.7. 不同批次之樣品，需各別進行一組品管樣品。

備註：

1. 相對離子強度之容許範圍參照歐盟 2002/657/EC 之規範，由鑑別離子與定量離子之波峰面積相除而得(<100%)，容許範圍如下：

離子比(%)	管制範圍(%)
>50	±20
>20~50	±25
>10~20	±30
≦10	±50

2. 本檢驗方法之食品包裝紙之檢出限量為 2 ng/g，鍋具依鍋底面積而有所不同(單位為 ng/cm^2)故以儀器定量極限(Limit of quantitation, LOQ)為 0.2 ng/mL 為檢出限量。
3. 本檢驗方法步驟若有影響檢驗結果之物質或背景干擾時，應先行探討排除。

參考文獻

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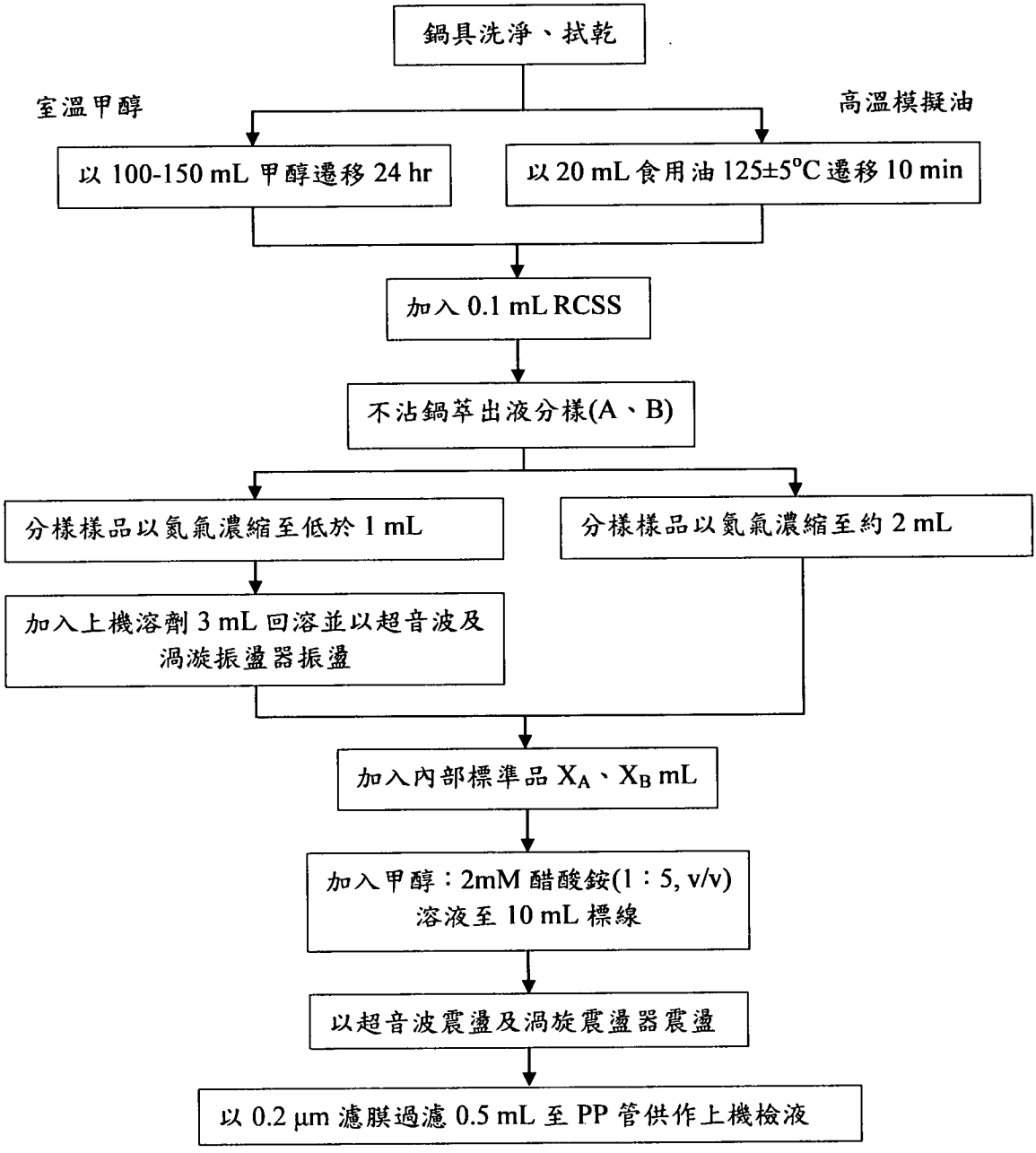
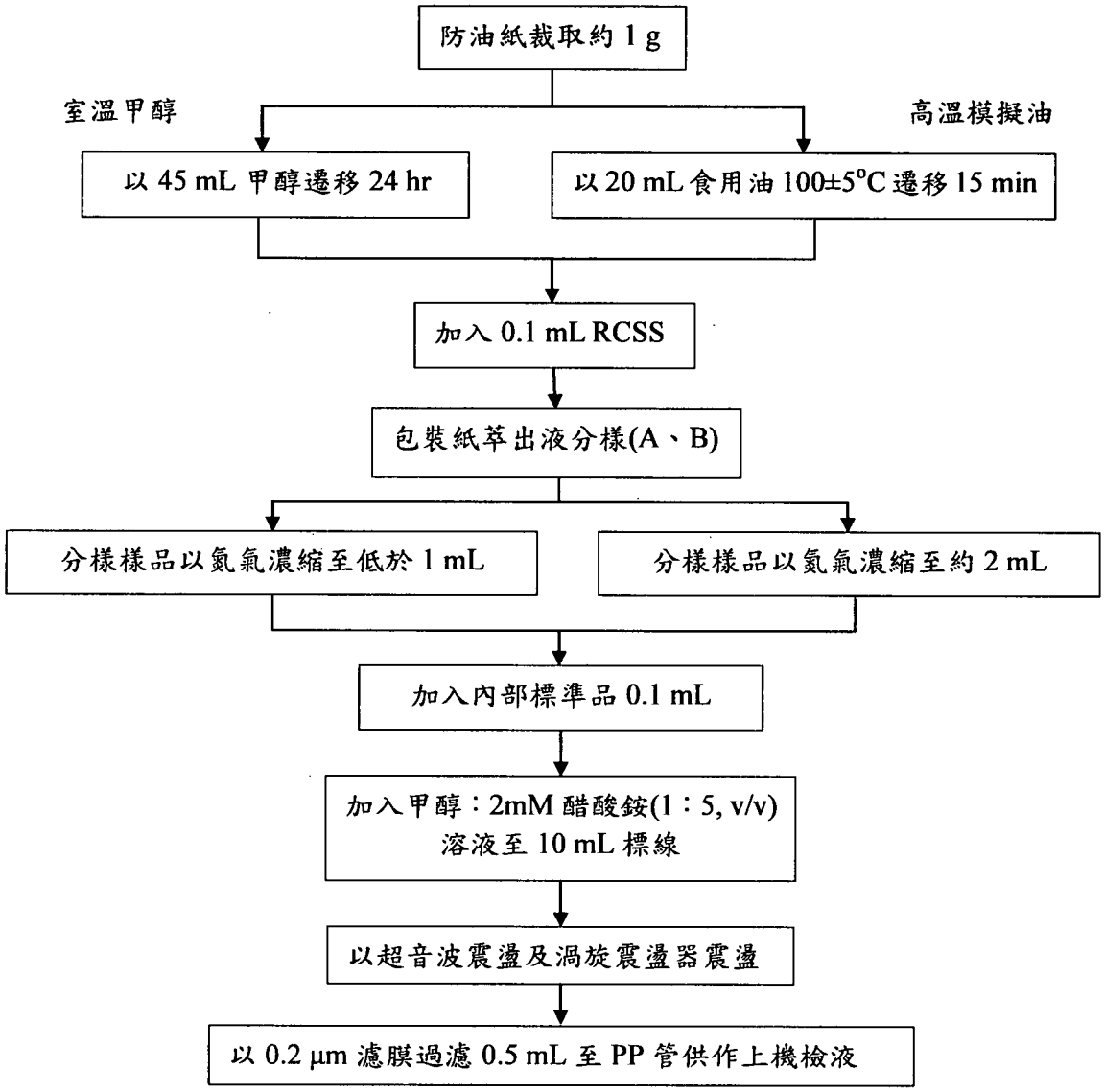


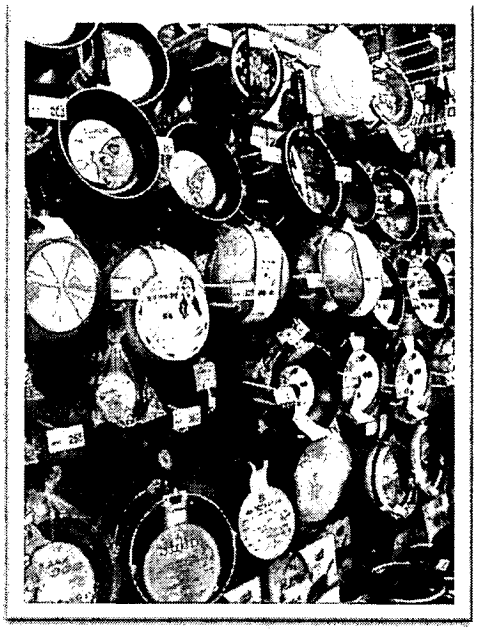
圖一 本研究研擬之不沾鍋 PFOA 檢測分析方法流程圖



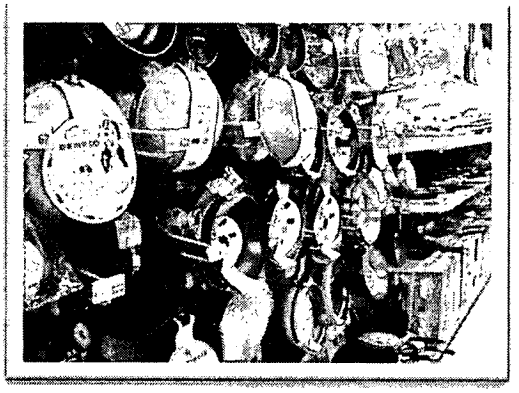
圖二 本研究研擬之食品包裝防油紙檢驗分析方法流程圖

附件 E　不沾鍋與防油紙採樣照片

賣場人員解說油品特性及銷售量



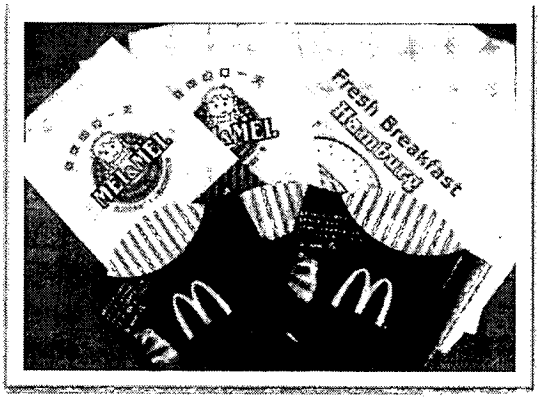
賣場內各式各樣不沾鍋具



賣場鍋具專區

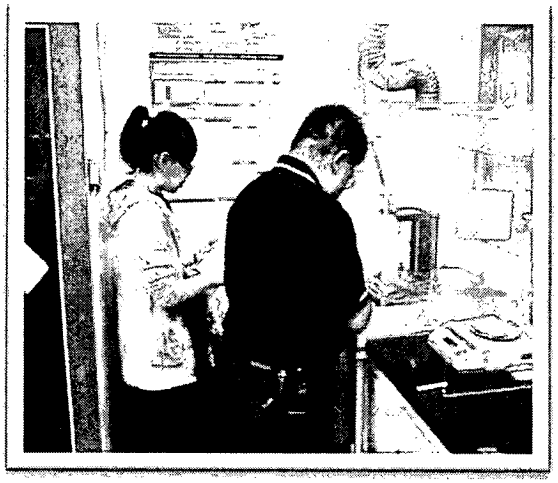
記錄不沾鍋標示資料並建檔

記錄賣場防油紙標示資料並建檔

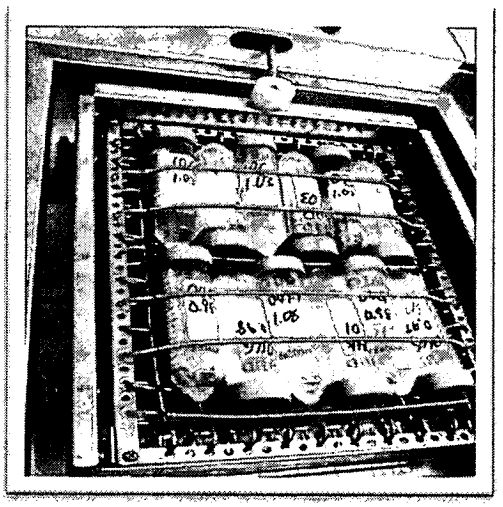


記錄坊間防油紙資料並建檔

附件 F　檢驗分析照片



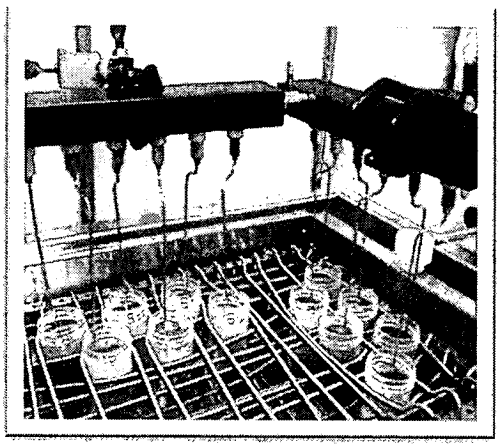
遷移試驗-防油紙秤重



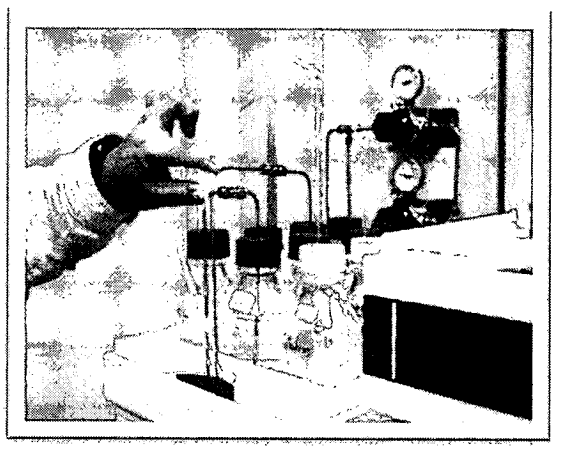
遷移試驗-室溫 24 hr 遷移

室溫 24 hr 遷移後

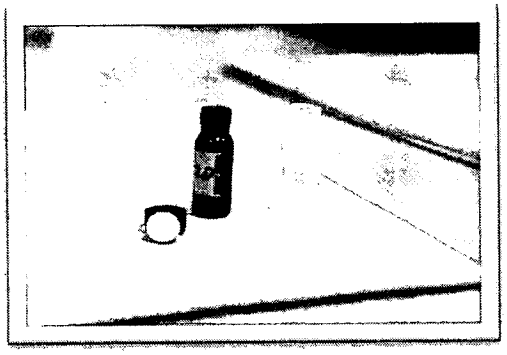
遷移試驗-添加 RCSS



遷移試驗-吹氮濃縮



消除背景干擾-原 PTFE 管線更替為不鏽鋼管



消除背景干擾-更換為 PP 樣品瓶

消除背景干擾-C18 SPE 淨化

江舟峰教授及研究助理們與 HPLC/MS/MS

附件 G　三路徑之食品接觸物件 PFOA 健康風險評估之 Excel 模式

TFDA Health Risk Assessment 3-Pathway Excel Model for PFOA Migration from Food Contact Articles

China Medical University, Health Risk Assessment Laboratory, PI C.F. Chiang, Programmer: H.C. Hsu, Nov 2010

This model estimates specific migration limit (SML) in ng/cm^2 for chemicals migrated from food contact articles with multiple pathways.
This is a 3-pathway PFOA model via oral intake: 1.food and drinking water, ADD_{fw} 2.food contact articles, ADD_c 3. non-food pathway , ADD_{nf}
Simulated senarios:3 subgroups*3 exposure senarios(A, B, C)*2 estimates(P50, P95) =18 combinations(non-stick cookware and oil resisitant paper)
Monte Carlo simulation:two variables of BW and IR_f (n=10000)

Subgroups=7-18 yrs

BW (kg)=N(46.5,16.43) IR_f (g/d)=N(2198,649.5) TDI=1500 ng/kg-d CF_{pan}=0.17 CF_{oil}=0.2

Non-stick cookware

	ER_{fw}	ER_c	ER_{nf}	SML(ng/cm^2)	
				P50	P95
A	0.5	0.23	0.27	69.5	24.8
B	0.6	0.13	0.27	39.0	13.7
C	0.7	0.03	0.27	9.0	3.4

Oil-resistant paper

	ER_{fw}	ER_c	ER_{nf}	SML(ng/cm^2)	
				P50	P95
A	0.5	0.23	0.27	58.9	20.9
B	0.6	0.13	0.27	32.9	11.7
C	0.7	0.03	0.27	7.6	2.7

Subgroups=19-59 yrs

BW (kg)=N(64.49,41.06) IR_f (g/d)=N(2257,841.8) TDI=1500 ng/kg-d CF_{pan}=0.17 CF_{oil}=0.2

Non-stick cookware

	ER_{fw}	ER_c	ER_{nf}	SML(ng/cm^2)	
				P50	P95
A	0.5	0.23	0.27	84.4	18.3
B	0.6	0.13	0.27	48.2	10.4
C	0.7	0.03	0.27	11.2	2.4

Oil-resistant paper

	ER_{fw}	ER_c	ER_{nf}	SML(ng/cm^2)	
				P50	P95
A	0.5	0.23	0.27	72.0	15.7
B	0.6	0.13	0.27	40.7	8.6
C	0.7	0.03	0.27	11.7	1.0

Subgroups=60+ yrs

BW (kg)=N(61.99,29.58) IR_f (g/d)=N(2147,613.2) TDI=1500 ng/kg-d CF_{pan}=0.17 CF_{oil}=0.2

Non-stick cookware

	ER_{fw}	ER_c	ER_{nf}	SML(ng/cm^2)	
				P50	P95
A	0.5	0.23	0.27	93.4	24.3
B	0.6	0.13	0.27	52.8	14.3
C	0.7	0.03	0.27	12.2	3.3

Oil-resistant paper

	ER_{fw}	ER_c	ER_{nf}	SML(ng/cm^2)	
				P50	P95
A	0.5	0.23	0.27	79.5	22.1
B	0.6	0.13	0.27	44.7	12.6
C	0.7	0.03	0.27	10.4	2.8

附件 H　專家研討會議紀錄

食品器具包裝不沾鍋塗層使用加工助劑全氟辛酸(PFOA)之溶出情形調查及健康風險評估專家研討會

全氟辛酸(PFOA)為不沾塗層鍋具和防油紙之關鍵化工原料，由於其極佳的化學阻抗性及界面活性，已被廣泛使用於各種商品，如膠帶、化妝品、清潔劑、塗料、及電子產品等，因此，可能的暴露途徑眾多。美國環保署 2006 年之「全氟辛酸安全評估報告」，將其列為「可能致癌物」。 PFOA 具有生物累積性及毒性，可在人體內存留長達數年，在一般民眾的血液中可被檢出。一般認為不沾鍋塗層可能殘留之 PFOA 含量極少，然而若加工不良或使用不當，可能會增加暴露風險。另於披薩盒與微波爆玉米花袋子等各種防油紙袋中，也曾發現含有 PFOA。

2009 年斯德哥爾摩公約(Stockholm Convention)會議 (SCPOP, 2010)，已將 PFOS 列管為「持久性有機污染物(Persistent organic pollutants, POPs)」，歸類於 Annex B (Restriction)，限制其製造與使用。由於 PFOA 與 PFOS 結構及性質相近，為保障民眾飲食安全，有必要針對不沾塗層鍋具及防油紙之 PFOA 問題，彙集各界專家學者意見，特召開本研討會。

- 會議時間：2010 年 9 月 15 日(星期三)
- 會議地點：行政院衛生署食品藥物管理局 501 會議室
- 指導單位：行政院衛生署食品藥物管理局
- 主辦單位：中國醫藥大學健康風險管理系、健康風險評估中心

99 PFOA 專 家 研 討 會 議 程

時間	主講人	議題	主持人/與談人
09:00～ 10:20	江舟峰	食品接觸物件全氟辛酸(PFOA)遷移之國際管理現況與趨勢	高怡婷 黃登福、鍾月容、高文彥
10:40～ 12:00	凌明沛	全氟辛酸(PFOA)毒理與食品接觸物件之健康風險評估	詹東榮 謝顯堂、陳石松、周子傑
12:00～ 13:30		Lunch Break	
13:30～ 14:50	潘復華	PFOA 與 PFOS 之檢測方法開發與品保品管	廖寶琦 何國榮、吳家誠、陳玉舜
15:10～ 16:30		綜 合 討 論	施養志 黃登福、鍾月容、高文彥 謝顯堂、陳石松、周子傑 何國榮、吳家誠、陳玉舜

專家研討會主持人、主講人名單

姓名	職稱	單位	備註
施養志	研究員	行政院衛生署食品藥物管理局	主持人
廖寶琦	教授	成功大學環境醫學研究所	主持人
詹東榮	副教授	台灣大學獸醫學系	主持人
高怡婷	科長	行政院衛生署食品藥物管理局	主持人
潘復華	簡任研究員	行政院環境保護署環境檢驗所	主講人
江舟峰	教授	中國醫藥大學健康風險管理系	主講人
凌明沛	助理教授	中國醫藥大學健康風險管理系	主講人

食品藥物管理局 PFOA 專家研討會

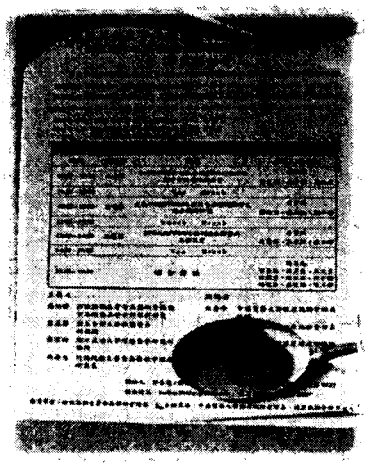
重點紀錄

江舟峰 (會議時間：2010.09.15)

1. 訂定 PFOA/PFOS 的環境標準時，應考量我們是受害者，要從嚴保護消費者。請研究團隊向經濟部查詢這些原料的進口量，並向環保署毒管處查詢環檢所於 2006 年在台灣 21 條河川監測的資料 (黃登福)。
2. 這是廣泛的環境與食品問題，政府須編列預算須儘速建立各種檢體的檢驗方法，特別是魚貝類的方法 。國人有高溫調理餐食之習慣，可能增加食品接觸物質(FCS)的溶出，應特別研究此一問題 (黃登福)。
3. 中央大學丁望賢老師的碩士班學生曾巧莉於 2004 年發表一篇名為用液相層析質譜儀檢測水樣及生物體中全氟介面活性劑的濃度之碩士論文，於 2006 年發表至期刊，該篇文獻中牡蠣樣品來自七股，魚體樣品則取自中壢漁市場，牡蠣 PFOA 高達 130 ppb，魚體肝臟 PFOA 達 120 ppb，這些數據是以乾重為基礎，另外中國也有檢測肉品中濃度，其中以雞肉濃度最高，約為 12.5 ppb，但是以濕重為基礎，建議研究團隊參考 (鍾月容)。
4. 研究團整理各國對此一議題的國際觀點，可再深入國內現有數據，多加延伸本土的觀點，特別是與 TFDA 相關的食品問題。關於江老師 Slide21 的資料顯示美國人血液有逐年上升的趨勢，但那已是 2005 年的研究，近年 USEPA C8 Stewardship program 的成效已顯示美國人體血液 PFOA/PFOS 之濃度已有降低的趨勢 (高文彥)。
5. 研究團隊風險評估的研究已具有相當的國際水準，模擬各種可能的風險情境，並進行機率分配運算，可以得出管制值 SML 的機率分配，提供給 TFDA 訂定標準時的重要參考，進行後續的風險管理 (謝顯堂)。
6. 為因應斯德哥爾摩公約，毒管處每年需提報環境監測報告。環檢所已於 2005 及 2006 年針對台灣 21 條河川，完成 PFOA/PFOS 的水體濃度監測 (潘復華)。
7. 檢測 PFOA/PFOS 時，應特別釐清各種可能背景干擾，包括管路、容器、試劑、蒸餾水及前處理等，所以 2007 年以前之檢測數據，必須證明已採行各種防範措施，才可為該公約接受。我們當時因成本較高，未採用同位素內標準品，建議中醫大應採用。環檢所已訂定檢測方法草案，待公告(潘復華)。

8. 台大團隊對竹科附近之客雅溪進行 PFOA 監測 (300 ng/L)，所得濃度較環檢所監測之南崁溪為 (80 ng/L)高，可能原因為前者為工業源放流水，後者為環境背景值 (林郁真)。
9. 環檢所的回收率均大於 100%，原因值得探討。該檢測方法係針對水體，若要檢測魚體，應特別考量基質特性與干擾 (何國榮)。
10. 進行風險評估所使用之 TDI，建議考量各種不同之毒性效應，如生殖毒性等 (詹東榮、周子傑)。
11. 為何不沾鍋及防油紙之 SML 單位不同，是否都應採用 ng/cm^2，請再研議 (陳石松)。
12. 進行風險評估時，除了監測濃度外，更大的不確定性係來自於暴露情境設定、暴露參數選用、由動物外推至人類之毒理參數等。我們需能更準確推估相對來源貢獻(RSC)，才能對本計畫 FCS 之 SML 提出更有意義的估算，情境設定與不確定分析在此將扮演重要的角色 (江舟峰)。

透過本計畫，中醫大團隊已建立此類工作的整合模式，將風險評估納入檢測與毒理數據納入風險評估，對於 TFDA 的進行後續法規訂定與管理，有實質助益。請業務單位將血液監測納入明年的工作重點，由成大的戴奧辛監測計畫提供檢體 (施養志)。



附件Ⅰ　食品接觸物件全氟辛酸(PFOA)之國際管理現況與趨勢 PPT

行政院衛生署
食品器具包裝不沾塗層使用加工助劑全氟辛酸(PFOA)
之溶出情形調查及健康風險評估
業者溝通會

食品接觸物件全氟辛酸(PFOA)之國際管理現況與趨勢

江舟峰 教授
中國醫藥大學 健康風險管理學系
健康風險分析中心
2010.12.01

1

簡報大綱

- PFOA/PFOS 食物與環境暴露與管制
  - 材質物化特性與商品應用
  - 食品、環境與人類暴露濃度 (OECD, 2002; Trudel et al, 2008)
  - 暴露評估與風險評估(EFSA, 2008)
  - PFOA飲用水標準(USEPA, 2009; UKHPA, 2008)
  - 歐美管制現況
- 食品接觸物質(FCS)之遷移與管制
  - 室溫遷移 (CFSAN 2005; USEPA, 2009)
  - 高溫+食物模擬物 (CFSAN, 2005; 2008)
  - USFDA/CFSAN 規範 (2007), OFAS's CEDI/ADI database, USEPA (2009)
  - European Standard (EN13130-1:2004), 中國指南 (GB/T 5009, 156-2003; GB/T 23296.1-2009)
  - 我國食品器具容器包裝衛生標準 (民98年)
- 結語與建議

2

全氟化物（Perfluorinated compounds, PFCs）

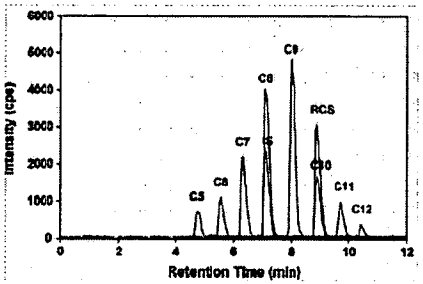
- 全氟化物 (PFCs)分為兩大類：
  全氟烷基羧酸 (Perfluoroalkyl Carboxylate, PFAC)
  全氟烷基磺酸鹽 (Perfluoroalkyl Sulfonate, PFAS)

- PFC最重要2個化合物 (C8)
  全氟辛酸 (Perfluooctanoic acid, PFOA): Teflon、塗層
  全氟辛烷磺酸 (Perfluorooctanesulfonic acid, PFOS): 用於半導體工業
  另有615種PFOA前驅物(precursor)、53種PFOS前驅物

3

PFCs家族(C5-C12)

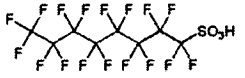
Members of PFCs	
PFPeA	C5
PFHxA	C6
PFHpA	C7
PFOA	C8
PFOS	C8
PFNA	C9
PFDA	C10
PFUA	C11
PFDoA	C12



Typical chromatogram of PFC with internal standard and recovery check standard . Liu et al., 2009).

4

PFOA及PFOS之物化特性

	PFOA	PFOS
中文名稱	全氟辛酸	全氟辛烷磺酸
結構式		
分子式	C8-H-F15-O2	C8-H-F17-O3-S
分子量	414.09 g/mol	500.13 g/mol
熔點	45 °C	40 °C
沸點	189 °C	133 °C
水中溶解度	9500 mg/L	570 mg/L

5

PFOA及PFOS之材料特性

- 材料特性

  具有良好的穩定性、不易分解、防水防油，耐熱耐腐蝕
- 應用於

  表面處理(不沾鍋、紡織品、地毯、家具等)

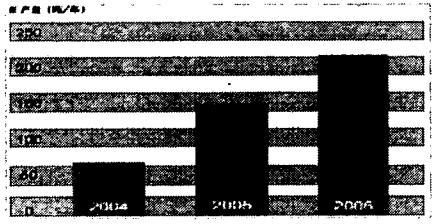
  紙張塗料(食品包裝容器、防油紙袋等)

  功能化學品(塗料、清潔劑、殺蟲劑、泡沫滅火器等)

6

PFOS年產量

- 1970-2002 總產量為10萬噸
- 2000 美國年產量3000噸
- 2002 3M公司停產PFOS
- 2004 中國PFOS產量50噸
- 2006 中國PFOS產量200噸 (50%外銷)

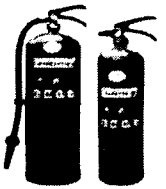


中國2004-2006年PFOS年產量(對，2008)

7

含PFOA/PFOS之日常用品





8

食品環境與人類之PFC流佈與劑量

三種水體中PFOA及PFOS濃度 (ppt) (EFSA, 2008)

country	PFOA(ng/L)	PFOS(ng/L)	Reference
Sea water			
Japan, Tokyo Bay	--	8-59	Taniyasu et al., 2003
Brazil, Guanabara Bay	0.7-3.25	0.4-0.92	Quinete et al., 2009
River water			
Germany	500-640	--	Holzer et al., 2008
Drinking water			
Brazil	0.35-2.82	0.58-6.70	Quinete et al., 2009
Japan	2.3-84	0.16-22	Takagi et al., 2008
Italy	1.0-2.9	6.2-9.7	Loos et al., 2007
Spain	0.32-6.28	0.39-0.87	Ericson et al., 2008
China	<0.1-45.9	<0.1-14.8	Jin et al., 2009

台灣及一些國家河川PFOA/PFOS濃度 (Lo, 2009)

Region	Occurrence area	Sources	PFOA (ng/L)	PFOS (ng/L)	Reference
Taiwan	Xiaoli	1	17.3	82	Lin, 2009
Taiwan	Touchien	1	10.9	48.9	Lin, 2009
Taiwan	Keya	1	310	5440	Lin, 2009
Japan	Tsurumi River	STP	13.4-15.9	179.6-179.9	Zushi et al., 2008
China	Yangtze River	1, U, P	2.0-260	<0.01-14	So et al., 2007
China	Pearl River Guangzhou	1, U, P	0.85-13	0.9-99	So et al., 2007
Germany	Rivers	WWTP	10-23	1.7-16	Becker et al., 2008
N-Italy	Po River	1	2-337	2-12	Loos et al., 2008
	T'anaro River		1270	2	
U.S.A	Tannessee River	2	Nd-598	16.8-144	Hansen et al., 2002

1, industrial discharge; STP, sewage treatment plant; U, urban discharge; WWTP, wastewater plant; P, populated area.; 2, Highest by fluorochemical manufacturing facility

各類水產食品中PFOS濃度ppb(EFSA, 2008

	PFOS (ng/g)	reference
Europe		
Shrimps	19-520	Hoff et al., 2003
Crab	93-292	Van de Vijver et al., 2003
Bib	<10-39	Hoff et al., 2003
Fillet of flounder	93-230	Van Leeuwen et al., 2006
Mediterranean fish (livers)	<1-87	Kannan et al., 2002
Asia		
Crustaceans & molluscs	0.114-0.586	Nakata et al.,2006 So et al., 2006
Fish	0.38-2.93	Gulkowska et al., 2006 (China)
Crustaceans	0.58-13.9	
Molluscs	0.33-1.32	
Tilapia fish & oysters	35.8-47.2	Tseng et al., 2006 (Taiwan)
Crap & catfish (livers)	<0.3-41.6	Greenpeace, 2010 (China)

加拿大TDS之PFOA及PFOS濃度 ng/g (ppb) (Tittlemier et al., 2007)

composite	year	PFOA	PFOS
Beef steak	2004	<0.5	2.7
Roast beef	2004	2.6	<0.6
Ground beef	2004	<0.4	2.1
Luncheon meats, cold cuts	2004	<0.4	0.5
Fish, marine	2004	<0.5	2.6
Fish, freshwater	2004	<0.5	2.0
Pizza	1998	0.74	<1
Microwave popcorn	1999	3.6	0.98

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日本家中灰塵中PFOA/PFOS濃度 ng/g (Moriwaki et al., 2003)

Entry	n	PFOS	PFOA
1	1	35	170
2	1	27	180
3	1	22	220
4	1	15	140
5	1	120	380
6	1	50	80
7	1	30	70
8	1	140	180
9	1	2500	3700
10	3	16±24	180±25
11	3	94±19	250±27
12	3	20±14	210±19
13	3	20±10	160±17
14	3	11±16	80±9.5
15	3	16±18	100±14
16	3	17±30	69±34

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日常用品中PFOA及PFOS濃度 ng/g (USEPA , 2009)

Category name	C8 (ng/g)
Dental floss and plaque	49.3
Treated apparel	62.9
Membranes for apparel	72.7
Treated home textile and upholstery	94.1
Pre-treated carpeting	134
Household carpet/fabric liquids and foams	358
Treated floor waxes and stone/woods sealant	637
Commercial carpet-care liquids	1850

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各地血庫 PFOS濃度ppb (OECD, 2002)

Plant Location	Year	Number of Persons Examined	Mean Levels (ppb)	Range (ppb)
US children (ages 2-12)	1995	599	Geometric mean: 37.5	6.7-515
St Paul, Minnesota (corporate staff or managers)	1998	31	47	28-96
Intergen, US (commercial source - donors)	1998	500	44	43-44
Sigma, US (commercial source - donors)	1998	200	33	26-45
US blood banks (donors)	1998	340-680	29.7	9-56
Sagamihara, Japan (plant management)	1999	32	40.3	31.9-56.6
Tokyo, Japan (plant management)	1999	30	52.3	33-96.7
Seattle, US (ages 65-96)	1999	238	Geometric mean: 31	34-175
Other commercial sources, US (lots)	1999	35	5	85
European blood banks, Belgium (pooled samples)	1999	6	17	4.9-22.2
European blood banks, Netherlands (pooled samples)	1999	5	53	39-61
European blood banks, Germany (pooled samples)	1999	6	37	32-45.6
US blood banks (American Red Cross, ages 20-69)	2000	645	Geometric mean: 34.9	4.3-1,658

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三國勞工歷年血液 PFOS濃度ppm (OECD, 2002)

Plant Location	Year	Number of Persons Examined	Mean Levels (ppm)	Range (ppm)
Decatur, Alabama, US	1995	90	2.44	0.25-12.83
	1997	84	1.96	0.10-9.93
	1998	126	1.51	0.09-10.6
	2000	263	1.32	0.06-10.06
	All years above		Geometric mean: 0.91	33.3-36.5[a]
Antwerp, Belgium	1995	93	1.93	0.10-9.93
	1997	65	1.48	0.1-4.8
	2000	258	0.80	0.04-6.24
Sagamihara, Japan	1999	32	0.135	0.048-0.63

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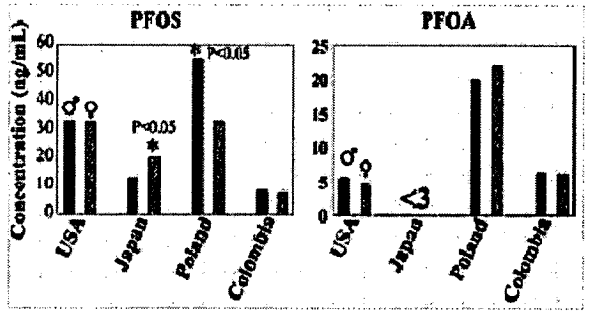
四國人民血液PFOS/PFOA濃度(ppb)比較 (Kannan et al., 2004)



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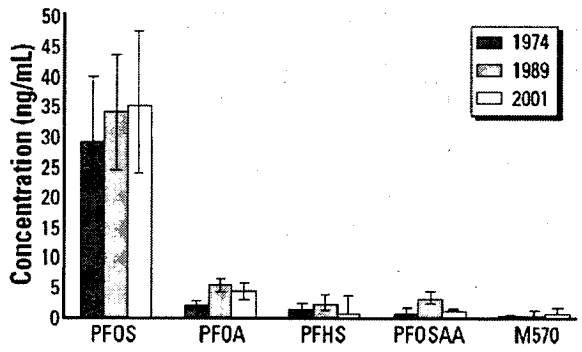
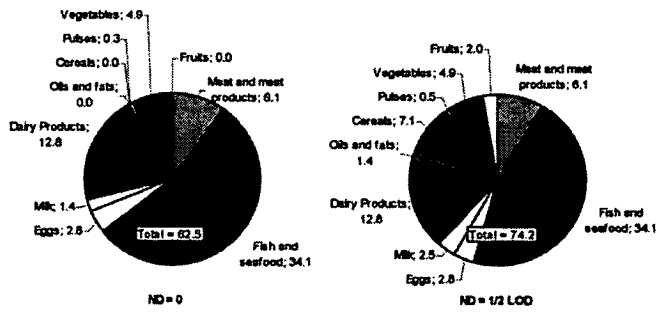
美國Maryland人體血液中濃度(ppb) (Olsen et al., 2005)



19

西班牙成人PFOS暴露劑量 ng/person-day (Ericson et al., 2008)



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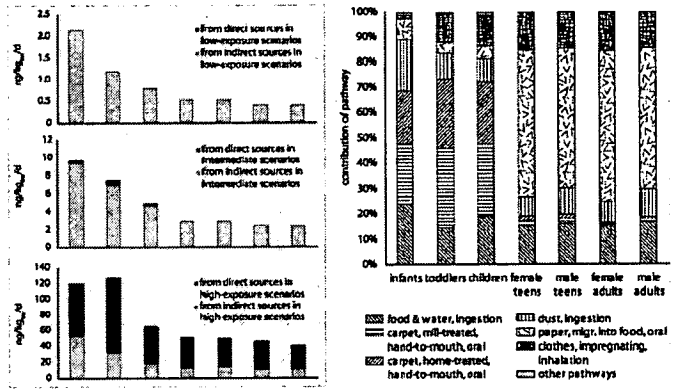
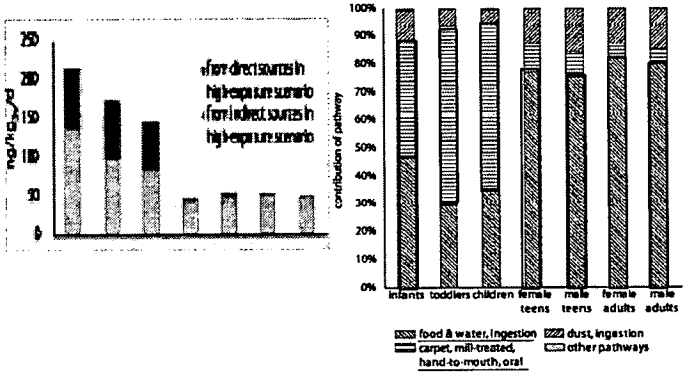
北美洲居民三種情境之各種途徑PFOA暴露劑量 ng/kg-d (Trudel et al., 2008)



北美洲居民高暴露情境之各種途徑PFOS暴露劑量(Trudel et al., 2008)



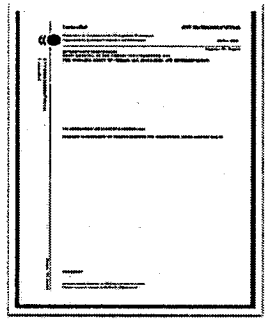
美國C8計畫大型流病調查結果

- Stephanie J. F. et al. (2010) PFOA and PFOS and serum lipids in children and adolescents, Arch Pediatr Adolesc Med, 164(9): 860-869.
- 參與個案n = 12,476 曾暴露於2000年Mid-Ohio River Valley之PFOA水源污染，該訴訟2002年和解
- 結果：2005-2006年血液平均值PFOA=69.2 ng/mL (ppb)、PFOS = 22.7 ng/mL，遠高於全國中間值，PFOA與膽固醇之低密度脂蛋白(LD Lipoprotein)正相關，PFOS與HDL有負相關，高血脂為新臟疾病的風險因子

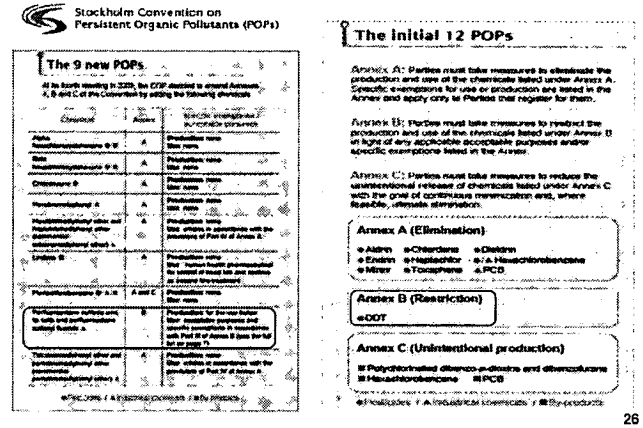
官方風險評估與管理措施

經濟合作發展組織PFOS危害評估報告 (OECD, 2002)

- 美國3M宣布2001停止全球生產後，OECD決議進行評估
- 半衰期：老鼠100天、猴子200天、人類數年
- 2-yr老鼠試驗證實會引起肝細胞腺瘤及甲狀腺囊瘤
- 流病研究顯示與膀胱癌有關
- 廣泛的環境暴露：水域、空氣、底泥、生活用品、食物等
- 職業暴露之血清濃度可高達13 ppm (1995)，一般族群為30-50 ppb
- 37 yr 職場追蹤調查，顯示癌症致死之風險並未增加，但膀胱癌顯著增加。
- 食入LD50 = 251 mg/kg，屬於中度極毒性
- 尚未有基因毒性之證據
- 生物累積(BCF)1000~4000



斯德哥爾摩公約 (Stockholm Convention, May 2009)



歐洲議會指令 (Directive 2006/122/ECOF)

- The Scientific Committee on Health and Environmental Risks (SCHER)認定PFOS為very persistent, very bio-accumulative and toxic，及長期的環境傳輸，為斯德哥爾摩公約規範之POPs
- 亟需進行長期的監測、風險評估與風險控管，飛機工業、半導體工業、照片工業無顯著風險，滅火泡沫需進一步評估，鍍膜工業必須減少空污排放
- 應持續監控既存污染，保護職場員工，最終予以禁用
- PFOA亦應受到同樣列管
- 任何物質PFOS濃度<0.005%，商品<0.1%，塗層<1 μg/m^2 (0.1 ng/cm^2)
- 2007/12會員國需完成法規訂定，自2008/6/27起實施，目前併入歐盟REACH法案管理

德國聯邦風險評估研究院(BfR, 2008)

- Health risks from PFOS and PFOA in food, Federal Institute for Risk Assessment (BfR, 2008)
- 德國 Federal Office of Consumer Protection and Food Safety (BLV)自2006年起進行3年的全國性魚類監測，但數據仍未足夠具代表性
- 動物實驗顯示POFS/PFOA均為hepatoxic, carcinogenic and reprotoxic
- 結論：食品暴露的健康風險為Unlikely，但淡水與海水魚PFOS的暴露不應忽略，仍需釐清河種魚類有較高的風險，同時其毒性、暴露劑量及其他暴露源仍待研究

歐洲食品安全局－一般意見(EFSA, 2008)

- Opinion of the scientific panel on contaminants in the food chain on perfluorooctane sulfonate (PFOS), perfluorooctanic acid (PFOA) and their salts, The EFSA Journal (2008)
- 食品PFOS/PFOA之分析數據相當欠缺，本報告中之暴露數據僅為建議性(Indicative)，且有些暴露可能源自其Precursors或其他間接來源，如鍋具、食品包裝、廚房灰塵等
- 流行病學的數據亦相當欠缺，人類危害之推估亦有高度之不確定性

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歐洲食品安全局–PFOA意見 (EFSA, 2008)

- PFOA濃度較PFOS低
- 魚體為PFOA重要的暴露途徑(35%)，但可能高估，飲用水佔15%
- 一般人ADD估計為2 ng/kg-day，高魚類食用者為6 ng/kg-day
- 成長為大人過程中，非食品暴露的比例逐漸降低，一般族群估計高達50%，主要經由室內空氣污染
- Liver為主要標的器官，發育毒性亦有可能
- 每日耐受量(TDI)估計為1500 ng/kg-day
- 直接食物暴露之危害商數(HQ)：一般人2/1500 =0.001、高魚類攝食者6/1500 = 0.004
- 目前一般人類族群血液中濃度值為Rat之0.01%
- 綜合結論：食品PFOA暴露目前尚不致造成危害效應，但考量其生物累積性，應持續監測其各暴露源

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歐洲食品安全局–PFOS意見 (EFSA, 2008)

- PFOS濃度較PFOA高，且於魚體Liver中均高於Filet
- 魚體為PFOS重要的暴露途徑(98%)，但目前數據可能高估，飲用水佔0.5%
- 一般人之均日劑量(ADD)估計為60 ng/kg-day，高魚類食用者為200 ng/kg-day
- 小孩成長為大人的過程中，非食品暴露的比例降低，一般族群估計約僅佔2%，高魚類食用者則更低
- Liver為主要標的器官，發育毒性亦有可能
- 每日耐受量(TDI)估計為150 ng/kg-day
- 直接食物暴露之危害商數(HQ)：一般人60/150 =0.4、高魚類攝食者200/150 = 1.3
- 目前一般人類族群血液中濃度值為Monkey之0.03~0.5%
- 綜合結論：食品PFOS暴露目前尚不致造成危害效應，但考量其生物累積性，應持續監測其各暴露源

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歐盟與英國之PFOA/PFOS暫行標準值

Species	Tolerable daily intake, TDI (ng/kg /day)	
	European Union (EU)	United Kingdom (UK)
PFOA	1500	3000
PFOS	150	300

[a] European Food Safety Authority, 2008
[b] Food Standards Agency Committee on Toxicity, 2006

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加拿大衛生署食品研究處 (FRD, 2009)

- 食品包裝不是食品中PFC的重要來源
- 加拿大TDS (2006, 2007)針對 meat, fish fast foods and food items prepared in their packing，尚無足夠數據可確認是否有某類食品普遍含有PFC
- 烘烤、水煮、煎炒魚類及貝類，可減少PFC濃度 54~100%
- 目前加拿大與英國的食品調查顯示濃度約為 ppb levels (ng/g)
- 北美大人及小孩血液均可廣泛測到PFC，說明食品為重要暴露途徑，2004 CTDS 估計食品PFOA暴露劑量 4.0 ng/kg-day，無健康虞慮
- 加拿大政府已將PFOS列入其Canadian Environmental Protection Act之 Toxic Substance List，並已提出Risk Management Strategy，以減少或消滅PFOS排入環境中

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美國EPA/SAB之PFOA風險評估報告(2006)

- SAB Review of 2005 EPA's draft risk assessment of potential human health effects associated with PFOA and its salts
- 因應Office of Pollution Prevention and Toxics (OPPT)之請求
- 作用模式(MOD): 過氧化物酶體增殖物活化受體 (PPAR-alpha for rodent liver tumor)
- 致癌物分類：3/4 Class B (likely), 1/4 Class C (suggestive)
- Endpoint: 以肝臟增生作為非致癌效應之endpoint，但未能達成以致癌效應為endpoint之建議
- 種間不確定係數：使用10有高度不確定性，BMD方法較NOAEL方法好
- 人類數據不足，難以推算"暴露幅度" (margin of exposure, MOE)

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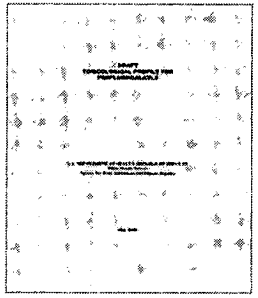
美國毒物及疾病登記署 – Toxicological Profile (ATSDR, 2009)



- 因應1986年之Superfund Act (List of Priority Hazardous Substance)
- 根據ATSDR及EPA訂定之指引，撰寫特定讀物"毒理特徵"，經內部及外部專議後，提供專家參考
- 2005年已完成275個評估
- 重點: 民眾易懂公衛聲明、人體暴露劑量、危害效應、欠缺資料

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美國毒物及疾病登錄署 – Fact Sheet (ASTDR, 2009)

- 針對一般大眾，以Q&A形式撰寫
- 民眾關心議題：化學品?暴露途徑?健康效應?孕重效應?政府建議事項?

Highlights: Exposure can occur from ingesting contaminated food or drinking water or breathing contaminated air. Treated carpets can be an important source of exposure for children. Workers exposed to perfluoroalkyls have not shown significant adverse effects. Little research has been done on the general population to determine whether these chemicals may cause adverse health effects. A few studies of pregnant women found higher levels in maternal blood to be associated with slightly lower weight of the babies.

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USEPA 2010/2015 PFOA 八大製造商監管方案

- 2006年10月31日，USEPA邀請8大主要PFOA聚合物製造商 (Arkema, Asahi, Ciba, Clariant, Daikin, 3M/Dyneon, DuPont, Solvay Solexis)
- 以2000年為基礎，承諾：
  2010年前削減全球95%污染排放量與該類產品含量
  2015年前，達100%消除(Elimination)
- 本方案不針對使用這些原料的物件(Cookware, carpet, textiles, paper)

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食品接觸物質(FCS)之遷移暴露

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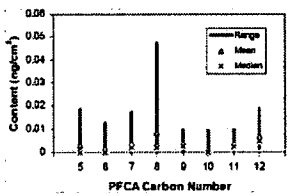
不沾鍋中室溫溶出C5-C12之分佈 (USEPA, 2009)

Unit in ng/cm²



Sample ID	C5	C6	C7	C8	C9	C10	C11	C12	FCS Percent (%)
L1	BDL	BDL	BDL	BDL	BDL	(3.9×10⁻¹)	BDL	2.0×10⁻¹	1.7×10⁻²	15
L3	1.5×10⁻²	BDL	1.1×10⁻¹	1.1×10⁻¹	NR	2.0×10⁻¹	BDL	1.0×10⁻¹	1.1×10⁻²	98.9
L4	NR	NR	NR	NR	1.8×10⁻¹	NR	NR	NR	NR	99.8
L5	NR	NR	NR	NR	1.3×10⁻¹	NR	NR	NR	NR	99.4
L6	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.7×10⁻²	99.2
L7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.8×10⁻²	99.5
L8	BDL	1.3×10⁻¹	BDL	BDL	BDL	BDL	BDL	1.5×10⁻²	98.8
L9	BDL	BDL	2.5×10⁻²	4.8×10⁻²	4.1×10⁻²	BDL	2.5×10⁻²	1.2×10⁻²	98.3
L10	NR	BDL	4.8×10⁻²	BDL	1.8×10⁻²	BDL	1.0×10⁻¹	4.0×10⁻²	99.5
L11	BDL	BDL	NR	1.5×10⁻¹	5.6×10⁻²	BDL	1.5×10⁻¹	1.9×10⁻²	99.6
L12	BDL	BDL	1.8×10⁻²	BDL	BDL	BDL	BDL	1.5×10⁻²	99.2
L13	1.5×10⁻²	1.5×10⁻¹	1.2×10⁻¹	1.2×10⁻¹	4.8×10⁻²	1.9×10⁻²	4.5×10⁻²	1.5×10⁻²	99.3
L14	NR	1.5×10⁻¹	9.8×10⁻²	1.2×10⁻¹	2.5×10⁻²	BDL	2.6×10⁻²	9.6×10⁻³	99.4

[1] Results for sample L2 failed to meet data quality requirements.

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不沾鍋及防油袋產品之PFOA 50 °C/24 hr遷移量(Begley, et al, 2005)

	Concentration of PFOA (μg kg⁻¹)
PTFE cookware	4–75
Dental floss (PTFE based)	3
Dental tape (PTFE based)	4
PTFE film/sealant tape	1800
FEP (fluoro-ethylene-propene copolymer) tubing	n.d.
Popcorn bags[1]	6–290
Hamburger wrapper	n.d.[1]
Sandwich wrapper[1]	n.d.
French fry box[1]	n.d.
Paper plates (soak-proof shield)[1]	n.d.
Perfluoro paper coatings (not applied)	88 000–160 000

[1]Paper products were not necessarily treated with perfluoro paper coatings.

PTFE cookware 50°C，24 hr

Table I. Concentration of fluorochemical in microwavable popcorn after microwave heating.

Brand	Concentration (mg kg⁻¹)
A	2.3
B	1.4
C	3.9
D	1.4
E	1.5
94% fat-free	<0.5

1 μg/kg=1 ng/g
1 mg/kg=1000 ng/g

4–75 ppm = 0.04–0.8 ng/cm²

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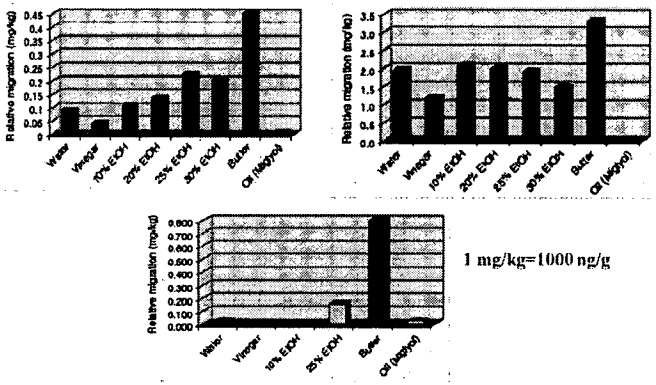
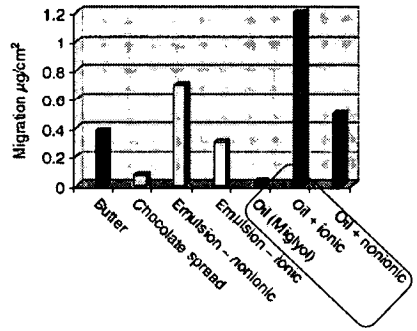
防油紙三種全氟辛烷磷酸(PFOP)於各類模擬物100 °C/15 min遷移量(Begley et al., 2008)



1 mg/kg=1000 ng/g

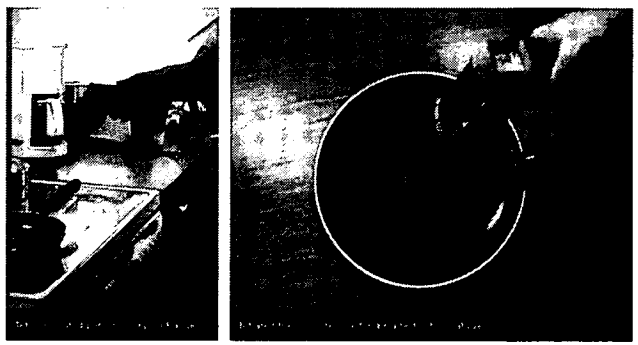
41

防油紙全氟辛烷磷酸(PFOP-A)40 °C/24 hr各種油品模擬物之遷移量(Begley et al., 2008)



42

FTIR檢測不沾鍋塗層材質



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美國食品安全及營養中心FCS指引(CFSAN, 2007)

- Guidance for industry: preparation of premarket submissions for food contact substances (FCS): chemistry recommendation (December 2007)
- 為非強制性之規範
- 包括FCS分解後產物及不純物
- 應繳交數據: "max use level" (in article), range of possible uses (films, molded articles, coating), max thickness and/or wt per unit area, food types, max temp and time, stability of FCS

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美國食品安全及營養中心FCS指引 –遷移試驗方法要項(CFSAN, 2007)

1. 遷移試驗方法與容器 (Migration cell)
2. 試體 (Specimen)
3. 溶媒選用 (Food simulant)
4. 暴露溫度與時間
5. 最終試驗 (End test or compliance test)
6. DC與EDI計算方法

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美國食品安全及營養中心FCS指引 –遷移容器(CFSAN, 2007)

- 若為容器類，可直接注入Food simulant
- 若為平板類，使用One-sided migration cell
- 未能溶出足夠遷移量，使用Two-sided migration cell (total submersion)
- 溫和攪拌以避免Localized solubility limitation

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美國食品安全及營養中心FCS指引 –試體(CFSAN, 2007)

- 塗料業者申請時，需提供 Formulation、試體厚度與表面積
- 若試體厚度>0.05 cm，且遷移量<25%理論遷移量，各面可視為獨立遷移，暴露面積以兩面計算，否則僅計算單面
- 紙類的遷移屬於 Solubility (not diffusion) driven，所以不論厚度，均應以單面計算

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美國食品安全及營養中心FCS指引 –溶媒(CFSAN, 2007)

- 水性及酸性食物 – 10% ethanol
- 高低酒精性食物 – 10或50% ethanol
- 油脂性食物 – Food oil (eg. corn oil) HB307, Miglyol 812 or others

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美國食品安全及營養中心FCS指引 –溫度與時間(CFSAN, 2007)

- 實際使用時最嚴格的暴露條件
- 貯存容器：室溫40 °C/10天，或20°C/6-12月
- Polymer材質40°C/10天之遷移值，可外插至30天
- 四時段暴露時間採樣：如2, 24, 96, 240 hr
- 每一種試體3重複，取平均值
- RCSS : 1/2, 1, ,2倍遷移濃度
- DC<0.1 mg/kg, R = 60~110%, Cv <20%
  DC>0.1 mg/kg, R = 80~110%, Cv<10%

美國食品安全及營養中心FCS指引 – DC/EDI計算(CFSAN, 2007)

- MC取三重複之平均值，單位 mg/in²及 mg/dm²
- 使用慣用值 10 g food per in²計算 Dietary conc (DC, mg/kg, ppb)
- DC, mg/kg = Σ (遷移濃度 MC_T × 食品總類分配係數 f_T)
  EDI, mg/kg-d= 3 kg food/head-day x DC, mg/kg x head/10 kg bw x CF
  其中CF = consumption factor每日攝食量與該材質接觸比例

- 計算LOQ in mg/in²及 mg/dm²
- 3重複遷移試驗，添加標準品，濃度½, 1, 2 倍預期濃度
  If DC<0.1 mg/kg, R= 60-110%, RSD<20%
  If DC>0.1 mg/kg, R= 80-110%, RSD<10%
- 若Fickian diffusion遷移，可以使用Arrhenius eq預測高溫遷移

美國食品安全及營養中心(CFSAN) –計算例

- 若預期有較低 Use level，可僅以計算方式估計Dietary conc
- 若Max use level =1 mg/kg food, unit wt = 50 mg/in²
- MC = (1 mg/kg)(50 mg/in²)(1 kg/10^6 mg) = 5×10^{-5} mg/in²
- Default assumption = 10 gm food/in²
- DC = (5×10^{-5} mg/in²)(in²/10 g)(1 g/10^3 mg) = 5 ppb

美國食品添加劑安全局(OFAS) – CEDI/ADI資料庫查核

- 參考OFSA建立之食品接觸物質(FCS)資料庫，作為申請食品廠商上市 (premarket notification)之用
- 目前共1267種FCS食品濃度(Dietary conc, DC)及累計每日攝食量(Cumulative estimated daily intake, CEDI)
- 比較廠商之EDI與CEDI，決定在暴露條件下，是否需進行後續毒理試驗
- PFOA，DC = 0.12 ppb (μg/kg)，CEDI = 6 ng/kg-day
- 若未列於資料庫者，DC = 7 ppb，CEDI = 350 ng/kg-day (PFOS?)

美國環保署FCS遷移試驗 (USEPA, 2009)

- USEPA, National Risk Management Research Lab (2009), PFOA content in 116 articles of commerce.
- 不沾鍋(1) 以RCSS之methanol 100~150 mL浸泡鍋面約0.3 mm深(2) 表面以aluminum foil密封避免蒸發(3) 於室溫萃取24 hrs (4) 蒸餾濃縮至約1 mL。
- 防油紙(1) 以不銹鋼刀切割樣品約1 g (5x5 cm) (2) 將樣品置入Surrogate RCS之45-mL methanol之50-mL PE離心管中 (3) 以Nutating mixer於室溫萃取24hrs (4) 蒸餾濃縮至約1 mL。
- 品管：物件/RCS x 2, Simulant blank x 1; LOQ = 0.3 ng/mL for injection sample, 3 ng/g for solid article, calibration curve r^2 = 0.99, R = 100±20%
- 結果：不沾鍋 1~50 x10^{-3} ng/cm^2, 防油紙 2~420 ng/g

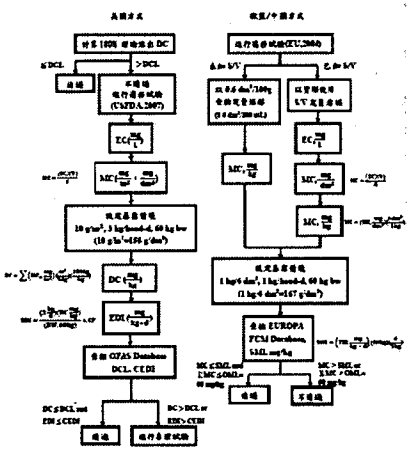
歐盟塑膠FCS遷移試驗指引 (2004)

- Material and articles intended come into contact with food (EC No 1935/2004)
- 網站：EUROPA>EC>DG Health and Consumers >Overview>Food and Feed Safety>Food Contact Materials
- 分為17大類：Adhesives, ceramics, cork, rubbers, glass, ion-exchange resins, metals and alloys, paper and board, plastics, printing inks, regenerated cellulose, silicones, textiles, vanishes and coatings, waxes, wood
- Overall migration limit (OML) for all the substances<60 mg/kg food
- Specific migration limit (SML) for each substance，根據ADI or TDI，終身暴露，重60 kg，每日食入1 kg食物，含有該FCS最大允許濃度
- PFOA之Substance No. 00468，屬於Plastics (9)之Additives (9.1)，目前尚未訂定SML

歐盟塑膠FCS遷移試驗指引(2004)

- Materials and articles in contact with foodstuffs – Plastics substances subject to limitation (EN 13130-1:2004)
- 中國標準(2009)也參考此一標準
- 章節：規範溶媒、溫度、時間、樣品、試驗容器、計算方法、物件成分分析、分析方法等
- 暴露面積：以單面暴露為原則，亦可採用更嚴格之切片(0.6 dm^2)全浸泡(Total immersion)，S/V=6 dm^2/L，但僅能計算單面面積，對稱性樣品可計算雙面面積，若切口厚度 > 0.5 mm，切口可以併入暴露面積(§10.3)
- Simulant A, distilled water; B, 3% HAC; C, 10% ethanol, D, rectified olive oil.
- 若S/V已知，且容器體積 <0.5 L或 >10 L，屬容器類以 mg/dm^2 (M) 表示，非屬容器類以mg/kg (C)表示，但C應換算為M再與SML比較
- 適用不沾鍋及防油紙

美國及歐盟FCS管制方式比較



中國食品用包裝材料及其製品的浸泡試驗方法通則 (GB/T 5009. 156-2003)

食品容器	定義	結果計算	備註
空心製品	大 容量大於等於1.1L，小於3L者； 小 容量小於1.1L者。	以測定所得毫克每升（mg/L）表示。	
扁平製品	置於水平位置時，製品內部裝能至盛滿液體時的液面的深度小於或等於25 mm的製品，如盒、碟。	● 遷移濃度單位為mg/L時，代入公式一： $a=\frac{cV}{2S}$ a：遷移濃度(mg/L)； c：溶出濃度(mg/L)； V：浸泡液體積(mL)； S：扁平製品參考面積(cm^2)； 2：每平方公分面積所需的溶劑毫升數。 ● 遷移濃度單位為mg/dm²時，代入公式二： $a_1=\frac{cV}{A}$ a_1：遷移濃度(mg/dm²)； c：溶出濃度(mg/L)； V：浸泡液體積(L)； A：樣品參考面積(dm^2)。	● 浸泡液體積為2 mL時，則測得之溶出濃度即樣品遷移濃度(mg/L)。 ● 浸泡液多於或少於每平方公分2 mL，則以測得之溶出濃度(c)按公式一計算。
耐熱器	容量大於等於3L的製品。		

我國食品器具容器包裝衛生標準(民98)

- 73.3.30公告，歷經7次改版
- 1. 一般規定：共分15類(防油紙是否列為No 15之紙類—其內部材質與內容物直接接觸之部分為塑膠類
- 2. 塑膠類規定：共分12類，並無PFOA類
- 3. 乳品用容器、包裝之規定：共分11類
- 規範：材質試驗項目及合格標準、溶媒、溶出條件、項目及合格標準
- 應釐清：單面或雙面暴露、合格標準之單位(為溶出濃度 ppm，1-#7~9類之玻璃、陶瓷器、施法瑯容器為MC)、暴露面積計算、溶媒體積等

我國食品器具容器包裝衛生標準(民98)

用途別	模擬食物溶劑	溶出條件	備註
pH 5以上之食品用器具、容器、包裝	水	60℃，30分鐘	食品製造加工或調理等過程中之使用溫度為100℃以下者。
		95℃，30分鐘	食品製造加工或調理等過程中之使用溫度為100℃以上者。
pH 5以下(含pH 5)之食品用器具、容器、包裝	4%醋酸	60℃，30分鐘	食品製造加工或調理等過程中之使用溫度為100℃以下者。
		95℃，30分鐘	食品製造加工或調理等過程中之使用溫度為100℃以上者。
油脂及脂肪性食品用器具、容器、包裝	正庚烷	25℃，1小時	
酒類用器具、容器、包裝	20%酒精	60℃，30分鐘	

結語與建議

- PFOA/PFOS對人類危害效應尚待確認，但美國(EPA C8)及歐盟(REACH)已訂定污染排放及物質減量、停產或特定工業限制使用時程，乃考量其POP長期不易分解之特性
- 歐美對PFOA/PFOS之TDI訂定仍有爭議，EFSA建議：1500/150 ng/kg-d
- PFOA暴露劑量2~6 ng/kg-d：食品35%、飲用水15%、非食品50%，HQ = 0.001~0.004
- PFOS 暴露劑量60~200 ng/kg-d：食品98%、非食品2%，HQ = 0.4~1.3
- FCS遷移管制：美國 EDI (mg/kg-d)<CEDI，歐盟與中國 MC (mg/dm²)<SML，歐盟另要求同類物質<SML(T)
- 我國FCS管制：較偏向歐盟方法，建議檢討相關辦法，釐清：遷移濃度計算、溶媒體積、暴露面積、管制標準等議題
- 一般認為食品接觸物件PFOA的風險甚低，但在國人特殊高溫烹煮條件下(油+離子/非離子性物質)，是否會成為重要暴露來源，應進一步釐清

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謝 誌

行政院衛生署食品藥物管理局

食品組、科技中心、研檢組

審查委員會

李俊璋、翁祖輝、詹東榮

中國醫大健康風險管理學系

健康風險分析中心

附件 J　業者溝通會議紀錄

食品器具包裝不沾鍋塗層使用加工助劑全氟辛酸之溶出情形調查及健康風險評估業者溝通會

指導單位：行政院衛生署食品藥物管理局

主辦單位：中國醫藥大學健康風險管理學系、健康風險分析中心

會議時間：99 年 12 月 1 日 星期三

會議地點：中國醫藥大學 立夫教學大樓 11 樓第二討論室

全氟辛酸(PFOA)為不沾塗層鍋具和防油紙之關鍵化工原料，由於其極佳的化學阻抗性及界面活性，已被廣泛使用於各種商品，如膠帶、化妝品、清潔劑、塗料、及電子產品等，因此，可能的暴露途徑眾多。美國環保署 2006 年之「全氟辛酸安全評估報告」，將其列為「可能致癌物」(Group B)。 PFOA 具有生物累積性及毒性，可在人體內存留長達數年，在一般民眾的血液中可被檢出。一般認為不沾鍋塗層可能殘留之 PFOA 含量極少，然而若加工不良或使用不當，可能會增加暴露風險。另於披薩盒與微波爆玉米花袋子等各種防油紙袋中，也曾發現含有 PFOA。

2009 年斯德哥爾摩公約(Stockholm Convention)會議 (SCPOP, 2010)，已將 PFOS 列管為「持久性有機污染物(Persistent organic pollutants, POPs)」，歸類於 Annex B (Restriction)，限制其製造與使用。由於 PFOA 與 PFOS 結構及性質相近，為保障民眾飲食安全，乃邀請食品接觸器具製造商、進口商與專家學者，共同探討了解 PFOA 國際議題及管理趨勢，並發表健康風險評估的本土研究成果，歡迎各界參與指導。

業 者 研 商 會 議 程

時間	主講人	議題	主持人/與談人
08:30 ~ 09:00		報到	
09:00 ~ 10:20	江舟峰	食品接觸物件全氟辛酸(PFOA)之國際管理現況與趨勢	高文彥
10:20 ~ 10:40		Tea Break	
10:40 ~ 11:20	江舟峰	我國食品接觸物件全氟辛酸(PFOA)溶出調查與健康風險評估	傅偉光
11:20 ~ 12:00		綜 合 討 論	謝顯堂 高文彥、傅偉光、陳錦樹 江伯源、宋鴻樟、黃惠瑛 王文忻、周子傑、凌明沛
12:00 ~ 13:00		Lunch (自由交談)	

行政院衛生署
食品器具包裝不沾塗層使用加工助劑全氟辛酸(PFOA)之溶出情形調查及健康風險評估業者溝通會議記錄

日期：99 年 12 月 01 日
時間：09：00 am~13：00 pm
地點：中國醫藥大學立夫教學大樓 11 樓

紀錄：張嘉津

壹、 內容

1. 行政院衛生署食品藥物管理局今年成立，希望能以健康風險評估與管理為架構，為國人的飲食安全把關，中醫大 PFOA 研究團隊在江舟峰老師的領導下，引進了風險評估的 3 個方法，引用的國際與官方文獻也很豐富。(高文彥)
2. 2005 年消基會發布不沾鍋會溶出有毒物質，造成不沾鍋業者由 25 家減為現在 5 家，導致大陸製造的廉價不沾鍋充斥台灣，建議政府盡速訂定管制標準，建立透明化的管理方式，讓產業也可以參與分享重要資訊，業者可以提供商業資料給學術界評估。我們已有 40 年經驗，也希望政府能輔導業者，製造出安全的鍋具產品，杜絕國外劣質品進來台灣。(勝立公司，李建標總經理)
3. 因為 C8 化合物的毒性考量，防油紙業者擬開發 C6，但 C6 較貴，而且不能完全達到 C8 的防油防水功能。我們是台灣最大的防油紙業者，每年產量約 200 公噸，我們定期將防油紙產品送 SGS 檢驗，都是合格的。希望能進一步接受評估輔導，研發安全的產品。(合眾公司，賴聰達主任)
4. 今年已建立常溫甲醇遷移試驗方法作為產品製造品質篩檢之參考依據，建議以後做高溫遷移，模擬國人特有烹煮條件。(傅偉光)
5. 中國醫大 PFOA 工作團隊在江舟峰老師的領導之下，首度進行這方面的研究，建立實驗分析方法，進行遷移試驗及定量分析，建立風險評估模式，建議特定遷移限值(SML)的管制值，個人認為已具有相當之國際水準。風險的評估是科學性的工作，但風險的管理為決策者責任，必須考量效益與成本等因素，今天報告限於風險評估的科學結論，業者的意見可以盡量在本溝通會上表達。(謝顯堂)

貳、會議結束

附件 K　期末審查簡報 PPT

行政院衛生署食品藥物管理局
99年度委託研究計畫
期末報告

計畫名稱：食品器具包裝不沾塗層使用加工助劑全氟辛酸(PFOA)之溶出情形調查及健康風險評估
計畫編號：99TFDA-TC-102
執行機構：中國醫藥大學健康風險管理學系
主 持 人：江舟峰
計畫期程：99年6月15日至99年12月31日(6.5個月)

1

期末工作整體執行情形

應完成工作	執行情形
1.蒐集國際食品安全管理資料	報告16、官網17、期刊12
2.蒐集國際PFOA遷移試驗方法	遷移試驗8、檢驗分析11
3.蒐集國內外PFOA溶出背景資料	食品18、環境33、血液7
4.建立儀器試驗方法	完成背景干擾查核、遷移試驗、儀器試驗方法初稿
5.調查我國食品接觸物件之PFOA遷移濃度	完成不沾鍋及防油紙各15件PFOA遷移濃度
6.設定風險情境，進行健康風險評估	設定18種風險情境，進行健康風險評估
7.召開專家學者會議	進行3場專題演講與1場綜合座談
8.召開業者溝通會議	進行2場專題演講與1場綜合座談

- 關鍵文獻：EFSA (2008), USFDA (2007), OFSA Web (2009), USEPA (2009), EU (2004), OECD (2002), Begley et al. (2005; 2008), Bononi and Tateo (2007), Trudel et al. (2008), Tittlemier et al. (2007), Ericson et al. (2008)
- Google雲端平台分享：4種計畫管理、3種成果、7種文獻等檔案資料

2

文獻中各種遷移試驗條件比較

	文獻出處	模擬調理條件
1	歐盟指引 (EU, 2004)	實際使用最嚴格烹調條件
2	USFDA (2007)	實際使用最嚴格烹調條件，考量 Simulant type 分配係數 (fi)，使用 4 種食品模擬物
3	Begley et al. (2005)	1. 不沾鍋及防油紙，粉末沸泡，50°C，24 hr 2. Microwaveble popcorn
4	Begley et al. (2008)	防油紙 1. 各類 Simulant：Water, Vinegar, 10-30% EOH, Butter, Miglyol, Oil＋ionic, Oil＋nonionic 2. 100°C, 15 min, Single-sided Migration cell
5	Bononi and Tateo (2007)	不沾鍋，先烹調 Tomato sauce 1. Oliver oil, 20 mL, 120-160°C, 10 mL 2. Potato stick, 50 mL preheated oliver oil, 10 min
6	USEPA(2009)	不沾鍋使用盛裝法，防油紙使用全浸泡，甲醇室溫暴露 24 hrs，過時攪拌

3

美國食品安全及營養中心(CFSAN)FCS 指引–試體(USFDA, 2007)

- 塗料業者申請時，需提供 Formulation、試體厚度與表面積
- 若試體厚度>0.05 cm，且遷移量<25%理論遷移量，各面可視為獨立遷移，暴露面積以兩面計算，否則僅計算單面
- 紙類的遷移屬於 Solubility (not diffusion) driven，所以不論厚度，均應以單面計算

4

美國食品安全及營養中心(CFSAN)FCS指引 – DC/EDI計算(USFDA, 2007)

- MC 取3重複之平均值，單位 mg/in²及 mg/dm²
- DC_T, mg/kg (ppm) = (MC_T, mg/in²) x (in²/10 g food) x(1000 g/kg)
- DC, mg/kg = Σ (DC_T x 食品總類分配係數 f_T)
- EDI, mg/kg-d= (3 kg food/head-d) x (DC, mg/kg) x (head/60 kg bw) x CF
  CF = consumption factor每日攝食kg與該FCS接觸比例
- 3重複遷移試驗，添加標準品，濃度 1/2, 1, 2 倍預期濃度
  If DC<0.1 mg/kg, R= 60-110%, RSD<20%
  If DC>0.1 mg/kg, R= 80-110%, RSD<10%
- 屬Fick's diffusion時，可使用Arrhenius eq預測高溫遷移

5

美國食品添加劑安全局(OFAS, 2009) – CEDI/ADI資料庫

- OFAS建立之食品接觸物質(FCS)資料庫，作為申請食品上市 (Premarket notification)之參考
- 目前共1267種FCS食品濃度(Dietary conc, DC)及累計每日攝食量(Cumulative estimated daily intake, CEDI)
- 比較廠商試驗推估之EDI與CEDI，決定在實際暴露條件下，是否需進行後續毒理試驗
- PFOA，DC = 0.12 ppb (μg/kg)，CEDI = 6 ng/kg-day
- 若未列於資料庫者，DC = 7 ppb，CEDI = 350 ng/kg-day (PFOS?)

6

歐盟塑膠FCM遷移試驗指引(EU, 2004)

- Materials and articles in contact with foodstuffs – Plastics substances subject to limitation (EN 13130-1:2004)
- 中國(2009)也據此訂定其指引
- 章節：規範溶媒、溫度、時間、樣品、試驗容器、計算方法、物件成分分析、分析方法等
- 暴露面積：以單面暴露為原則，可採用更嚴格之切片(0.6 dm²)全浸泡(Total immersion)，S/V=6 dm²/L(6 dm²/kg)，但僅能計算單面面積，對稱性樣品可計算雙面面積，若切口厚度> 0.5 mm，切口可以併入暴露面積(§10.3)
- Simulant A, distilled water; B, 3% HAC; C, 10% ethanol, D, rectified olive oil.
- 若S/V已知，MC以mg/dm²表示，否則以mg/kg 表示

7

歐盟遷移限值資料庫(EUROPA FCM Website)

- Material and articles intended come into contact with food (EC No 1935/2004)
- 網站：EUROPA>EC>DG Health and Consumers >Overview>Food and Feed Safety>Food Contact Materials
- FCM分為17大類：Adhesives, ceramics, cork, rubbers, glass, ion-exchange resins, metals and alloys, paper and board, plastics, printing inks, regenerated cellulose, silicones, textiles, vanishes and coatings, waxes, wood,共規範853種FCMs
- PFOA之Substance No. 00468，屬於Plastics (9)之Additives (9.1)，目前尚未訂定SML
- Overall migration limit (OML) for all the substances<60 mg/kg food
- Specific migration limit (SML) for each substance，根據ADI or TDI，終身暴露，重 60 kg，每日食入1 kg 食物，S/V=1 kg/6 dm²，訂定食物中FCM限值mg/kg

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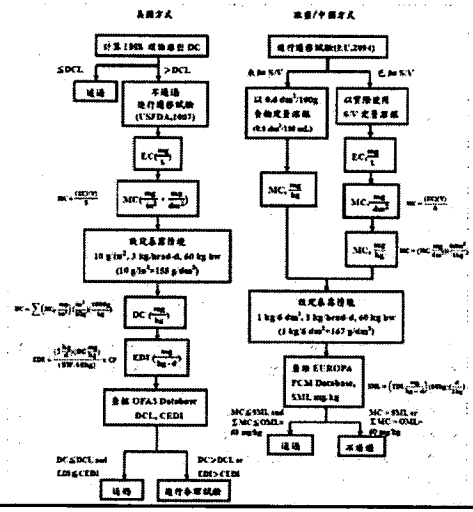
美國及歐盟FCS管制方式比較



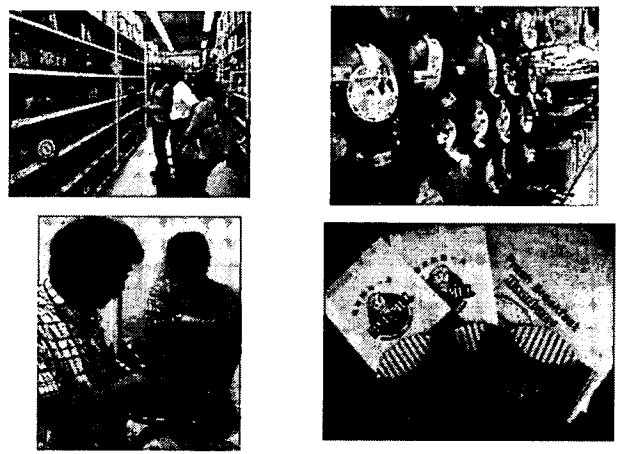
EFSA (2008) PFOA and PFOS Exposure Assessment

	PFOA	PFOS
$BMDL_{10}$/NOAEL	0.3 mg/kg/d	0.03 mg/kg/d
Overall UF	2x10x10	2x10x10
TDI for general population	1500 ng/kg/d	150 ng/kg/d
ADD (fish)	2 ng/kg/d (avg) 6 ng/kg/d (high)	60 ng/kg/d (avg) 200 ng/kg/d (high)
MOS = TDI/ADD	250 - 750	0.8 - 2.5
Serum level margin	1000	200~3000
Risk in general population	Highly unlikely	Unlikely

ADD: Average daily dose
MOS: Margin of safety (安全邊際，為hazard quotient之倒數)

結果與討論

現場採樣照片



不沾鍋具採樣調查結果(1/2)

	採樣地點	樣品編號	產地	材質	標稱直徑 (cm)	製造日期	價格 (NT.)	產品標示
1	大潤發	O990812A	台灣	鐵	14	98/12	67	新鍋使用前將鍋子洗淨，用紙巾拭乾，少許食用油預熱，小火料理。
2		O990812C	越南	鋁合金	26	99	309	新鍋使用前，裝八分滿的水煮沸，倒掉擦乾，以紙巾沾少量食用油擦拭鍋具，待鍋具冷卻後，以海綿中性清潔劑清洗，使用不沾鍋專用匙、木匙、木鏟
3	台糖	O990823K	中國	高級合金	28	–	299	第一次使用先將鍋具洗淨，溫火烘乾，倒入些許油均勻塗抹預熱，請勿空燒。使用木製、竹製或耐熱橡膠鍋鏟，勿使用鐵刷、強力菜瓜布或去汙粉清洗
4		O990823L	–	–	30	99/06	219	使用木製或耐熱鍋鏟，勿用尖銳金屬用具，勿用大火烹調，使用柔軟清潔布，勿用鋼絲球等尖銳物品清洗。
5		O990823M	中國	鋁合金	32	97/12	498	使用以小火溫鍋，避免大火及空燒，以海綿清洗，勿用硬質菜瓜布或鋼絲球。使用木質或無毒性樹脂鍋鏟，勿用金屬鍋鏟。
6		O990823N	中國	鋁合金	30	99/04	199	第一次使用前，先用豬油加熱或倒入熱牛奶煮沸抹拭鍋面，效果更好。
7		O990823O	中國	合金	26	–	149	使用前確認把手鍋具符合規格，以專用清潔劑清洗拭乾，燒焦黏著時用熱水浸泡，勿用刀子刮除。
8		O991117H	韓國	–	26	–	890	升溫快，勿用大火調理，加入少許油約30秒即達燃火點。

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不沾鍋具採樣調查結果(2/2)

	採樣地點	樣品編號	產地	材質	標稱直徑 (cm)	製造日期	價格 (NT.)	產品標示
9	愛買	O991117A	法國	鋁合金	30	–	699	新鍋使用前，裝八分滿的水煮沸、倒掉擦乾，以紙巾沾少量食用油擦拭鍋具，使用木鏟或不沾鍋專用鏟，勿用金屬鍋鏟，中小火烹調即可，避免空燒，用海綿、軟布及一般洗碗精清潔即可，勿用菜瓜布或金屬絲。
10		O991117B	中國	鋁合金	30	98	599	勿空燒，勿於鍋具中注滿水或油使用，燒焦黏著時浸泡熱水，勿用刀子刮除。
11		O991117C	–	輕合金	32	–	240	以中小火烹調，適用木產、竹鏟、尼龍鏟，使用後以棉質清洗器清潔。
12		O991117D	中國	複合金	30	–	699	新鍋使用前先用清潔劑清洗乾淨後抹上食用油，烹調時使用少量油及中小火，請勿空燒，並請使用溫度勿超過288°C，勿使用金屬或銳利器具炒菜，使用後勿以冷水立即清洗，勿以粗糙菜瓜布或鋼絲球大力擦洗。
13		O991117E	中國	鋁板	30	–	349	新鍋使用前，以溫的軟性清洗抹布沾沙拉酸等中性清洗劑將鍋子內外全部清洗乾淨，在鍋內裝入清水八分滿，至於瓦斯爐或電爐煮沸3~5分鐘，再以清水沖洗乾淨即可使用。不適用金屬鍋鏟。請勿空燒。
14		O991117F	中國	鋁合金	28	97	599	使用中請勿碰觸鍋具，油勿加入鍋具過半，油溫勿超過200°C，酸、酸類物質可能導致鍋具生鏽。
15		O991117G	中國	鋁合金	28	–	399	新鍋使用前用少許清潔劑清潔，抹上食用油，選用木鏟，中小火烹調，避免乾燒，使用後勿馬上注入冷水清洗。

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防油紙採樣調查結果

	地點	樣品編號	產地	材質	厚度(mm)	密度(g/cm³)	製造日期	價格(NT.)
1	大潤發	O990804F	台灣	–	0.06	0.005	–	38
2		O990804G	台灣	–	0.04	0.004	–	32
3		O990804H	台灣	–	0.04	0.004	–	29
4		O990804K	台灣	–	0.04	0.004	–	85
5		O990810A	台灣	紙漿	0.48	0.035	98/08/05	19
6		O990810B	台灣	長纖淋膜單面PE專用紙	0.48	0.036	98/09/05	11
7		O990810C	台灣	原木漿	0.04	0.004	96/06	132
8	早餐店	O990810E	–	–	0.07	0.005	–	–
9	雞排店	O990810F	台灣	–	0.04	0.006	–	–
10		O990823A	–	–	0.07	0.005	–	–
11		O990823B	–	–	0.07	0.005	–	–
12		O990823C	–	–	0.07	0.005	–	–
13		O990823D	–	–	0.07	0.005	–	–
14		O990823E	–	–	0.07	0.005	–	–
15	早餐店	O990823F	–	–	0.06	0.005	–	–

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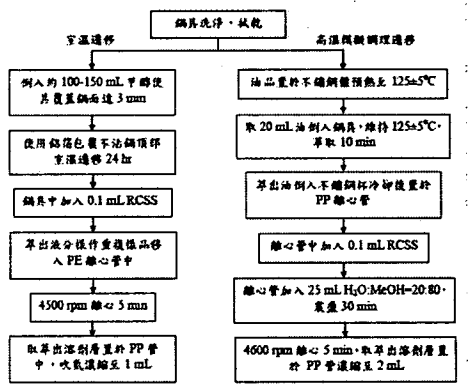
不沾鍋具遷移試驗流程圖



圖一 本研究研擬之不沾鍋 PFOA 遷移試驗方法流程圖

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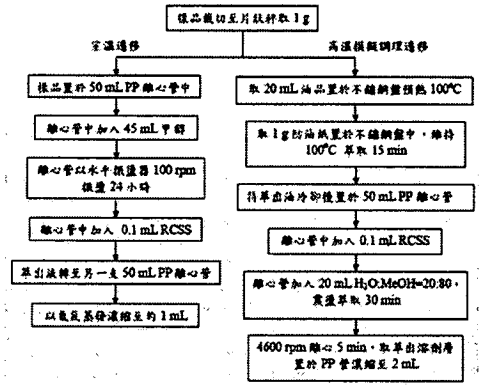
防油紙遷移試驗流程圖



圖二 本研究研擬之食品包裝防油紙 PFOA 遷移試驗方法流程圖

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本研究遷移試驗照片

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PFOA檢驗所使用之LC/MS/MS之儀器操作條件

HPLC[a]		ESI-MS/MS[b]	
層析管柱	型號：Agilent ZORBAX Eclipse XDB-C18 尺寸：2.1x50mm 3.5μm	電噴霧離子源	Collision gas（arbitrary unit (setting)） 5 Curtain gas （arbitrary unit (setting)） 10 Ion source gas 1 （arbitrary unit (setting)） 45 Ion source gas 2 （arbitrary unit (setting)） 60 IonSpray voltage (V) -4500 Temperature (°C) 500
保護管柱	型號：Agilent ZORBAX Eclipse XDB-C8 尺寸：2.1x12.5mm 5μm		
自動進樣器	注射量：10 μL		
管柱控溫器	管柱控溫：40 °C		
移動相緩衝	動相梯度條件：	串聯式質譜儀	監測離子對：

層析時間(min)	移動相百分比 移動相 A (%)	移動相 B (%)
-3.0 (管柱平衡)	80	20
0 (注射)	80	20
0.5	50	50
5.5	5	95
8.0	5	95
8.1	80	20
10.0	80	20

動相流速：0.3 mL/min

層析移動相 A：試劑水含 2mM 醋酸銨

層析移動相 B：甲醇

Analyte	Precursor ion (m/z)	Product ion (m/z)	DP (V)	CE (eV)
PFOA	413	369*	-45	-14
		169**	-45	-23
PFOA-$^{13}C_4$	417	372	-45	-14
PFDA-$^{13}C_2$	515	470	-55	-14

DP：Declustering Potential

CE：Collision Energy

* PFOA 定量離子

** PFOA 定性離子

[a]高效能液相層析儀(HPLC)：廠牌Agilent，型號1200

[b]電噴霧式串聯質譜儀(ESI-MS/MS)：廠牌AB，型號API5000

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PFOA檢驗方法之品質管制要求

	品質管制項目	管制範圍	文獻出處
1	檢量線線性	線性 r > 0.995	TFDA, 2010
2	回收查核擬似標準品(RCSS)	回收率60-110%	USFDA. 2007
3	檢量線確認	相對誤差 ±15%	USEPA, 2009
4	檢量線查核	相對誤差 ±15%	USEPA, 2009
5	重複樣品	相對偏差<20%	USFDA, 2007
6	方法空白樣品	<1/2檢量線最低濃度	TFDA, 2010
7	查核標準品	回收率100±20%	TFDA, 2010
8	質譜鑑別離子比	(參考註一)	EU, 2002

註一：質譜鑑別標準以鑑別離子層析峰面積/定量離子層析峰面積*

離子比(%)	管制範圍(%)
>50	±20
>20~50	±25
>10~20	±30
≤10	±50

European Union, 2002/657/EC

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PFOA檢驗方法之各種樣品之上機施打順序

分析類別	樣品上機順序	樣品類型[a,b]	備註
檢量線	1~5	5點檢量線	建立檢測濃度範圍
	6	檢量線確認	以不同於檢量線製作來源之標準品確認檢量線之適用性
批次樣品	1	檢量線查核	確認查核分析過程中使用的檢量線準確性決定此批次實驗是否須重新製作檢量線
	2	方法空白樣品	監測分析過程中是否遭受污染
	3	查核標準品	確認分析結果之準確度或品質
	4~13	樣品及重複樣品1~10	分析樣品及重複樣品
	14	檢量線查核	確認分析前後之品質

[a]所有樣品於前處理後，皆添加回收查核擬似標準品(RCSS)
[b]所有樣品皆於上機前添加內標準品(IS)

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消除PFOA背景干擾之各項措施

	原儀器使用之管件材質及溶劑	更換非PTFE管件材質及溶劑
1	PTFE材質之移動相溶劑抽取管	改為1/8"不鏽鋼管
2	PTFE材質之移動相溶劑瓶內過濾器接頭	改為以0.2 um之Nylon膜與先過濾動相溶劑
3	抽取管連接線上溶劑除氣裝置(Degaser)之膜片	不連接(Bypass)該除氣設備，事先以Supersonic去除氣泡
4	PTFE材質之動相Pump seal	改為PE材質之Pump seal
5	玻璃材質樣品瓶(吸附PFC)	改為PP材質之樣品瓶
6	PTFE材質樣品瓶蓋	改為PP材質之樣品瓶蓋
7	動相溶劑分注器PTFE管線	直接由溶劑儲存瓶倒出製備動相溶劑甲醇
8	動相試劑水(Mili-pore)	去離子水經C18 SPE淨化
9	玻璃定量瓶、儲存瓶、離心管	改用PP材質

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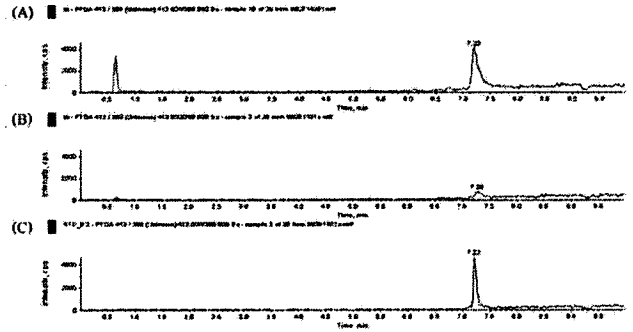
PFOA檢驗之背景干擾消除前後之圖譜



(A)儀器修改前注射空白之上機溶劑，訊號強度4100 cps (Counts per second)，S/N=46
(B)儀器修改後注射空白之上機溶劑，訊號強度800 cps，S/N=5.7
(C)儀器修改後注射2 pg (0.2 ng/mL注射10μL) PFOA，訊號強度4690 cps，S/N=69.3

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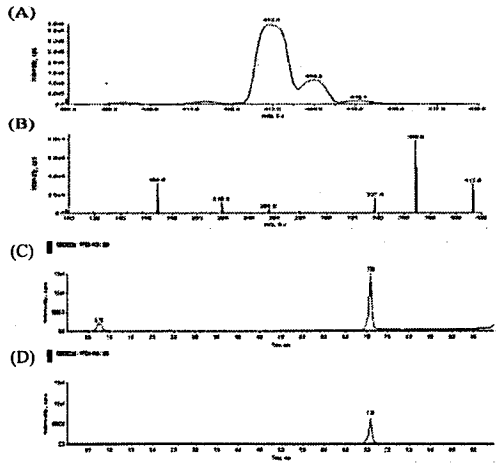
標準品及樣品之一圖譜



(A)PFOA標準品以single MS scan之質譜圖

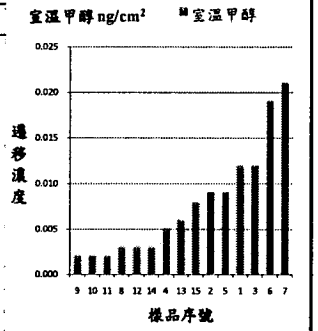
(B)PFOA標準品取m/z值413.0以product ion scan之質譜圖

(C)樣品編號O990823O定量離子對413/369之層析圖

(D)樣品編號O990823O定性離子對413/169之層析圖

不沾鍋室溫遷移試驗結果與品管執行情形

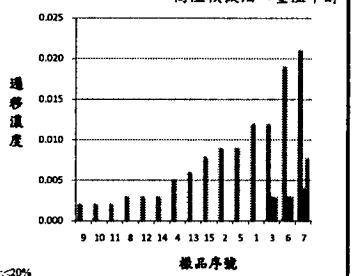
序號[a]	樣品編號	遷移面積 (cm^2)	遷移濃度 (ng/cm^2)[b]	RCSS (%)[c]	RPD(%)[d]
1	O 990812A	86.5	ND	96.6	0.9
2	O 990812C	292.4	0.009	83.5	0.9
3	O990823K	397.4	0.012	77.4	0.9
4	O990823L	386.9	0.005	86.9	0.9
5	O990823M	379.9	0.009	93.3	0.9
6	O990823N	383.4	0.019	84.8	0.9
7	O990823O	277.5	0.021	71.8	0.9
8	O991117H	274.5	ND	87.1	1.2
9	O991117B	482.8	ND	86.0	1.0
10	O991117C	478.9	ND	98.3	11.7
11	O991117D	452.2	ND	89.9	3.1
12	O991117E	329.9	ND	96.2	4.7
13	O991117F	169.6	ND	90.7	5.1
14	O991117G	329.9	ND	96.4	0.2
15	O991117I	268.7	0.008	90.7	9.6



[a]樣品#1-7為同一批物件樣品中取一樣品作為重複樣品，故有相同之RPD，樣品#8-15為各溶出液分樣樣品，其遷移濃度、RCSS及RPD為重複分析之平均值。
[b]定量極限：0.2 ng/mL (0.005 ng/cm²) [c]回收率要求60-110% [d]相對差異百分比<20%

不沾鍋高溫遷移試驗結果與品管執行情形

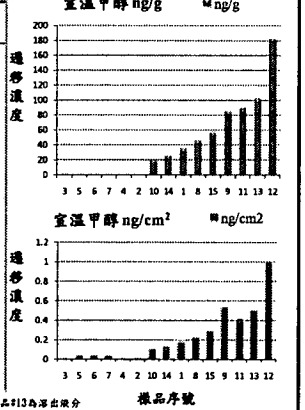
序號	樣品編號	遷移濃度 (ng/cm^2)[a]	RCSS(%)[b]	RPD(%)[c]
室溫甲醇				
3	O990823K	0.012	77.4	0.9
6	O990823N	0.019	84.8	0.9
7	O990823O	0.021	71.8	0.9
高溫模擬油				
3	O991123L	ND	94.7	1.4
6	O991123M	ND	90.5	0.3
7	O991123K	ND	94.2	4.4
高溫模擬油→室溫遷移				
3	O991123Q	ND	84.9	2.3
6	O991123R	ND	86.6	2.6
7	O991123P	0.0078	88.7	13.0



[a]檢出限量:0.2 ng/mL (0.005 ng/cm²) [b]回收率要求60-110% [c]相對差異百分比<20%

防油紙室溫遷移試驗結果與品管執行情形

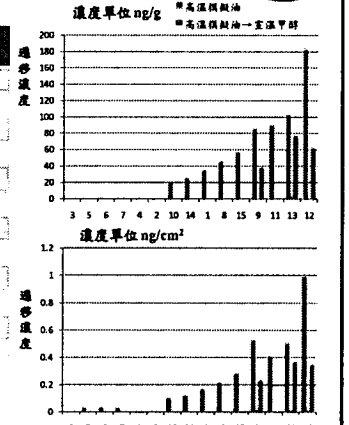
序號[a]	樣品編號	樣品厚度 (mm)	遷移面積 (cm^2)	樣品質量 (g)	遷移濃度 (ng/g)[b]	遷移濃度 (ng/cm^2)[c]	RCSS[d]	RPD[e]
1	O990804F	0.06	202.0	0.99	35.9	0.176	90.6	6.3
2	O990804G	0.04	245.0	0.98	ND	ND	101	6.3
3	O990804H	0.04	250.9	1.06	ND	ND	88	6.3
4	O990804K	0.04	233.5	1.01	ND	ND	110	6.3
5	O990810A	0.48	29.6	1.03	ND	ND	78.6	6.3
6	O990810B	0.48	29.0	1.03	ND	ND	94.5	6.3
7	O990810C	0.04	265.8	1.03	ND	ND	66	6.3
8	O990810E	0.07	215.9	1.02	46.6	0.22	86.2	6.3
9	O990810F	0.04	162.9	1.01	85.2	0.53	79.2	6.3
10	O990823A	0.07	186.1	0.94	20.4	0.10	106	0.9
11	O990823B	0.07	205.5	0.94	89.7	0.41	95.2	0.9
12	O990823C	0.07	186.2	1.01	183	0.99	89.8	0.9
13	O991123U	0.07	208.3	1.02	103	0.50	91.4	15.3
14	O990823E	0.07	193.7	0.92	26.2	0.12	102	0.9
15	O990823F	0.06	207.1	1.02	57.5	0.28	83.1	0.9



[a]樣品#1-6、8-15分別為二批物件樣品中各取一樣品作為重複樣品，故有相同之RPD，樣品#13為溶出液分樣樣品，其遷移濃度、RCSS及RPD均為重複分析平均值。
[b]定量極限：0.2 ng/mL (2.6 ng/g) [c]遷移濃度以單面面積計算 [d]回收率要求60-110% [e]相對差異百分比要求<20%

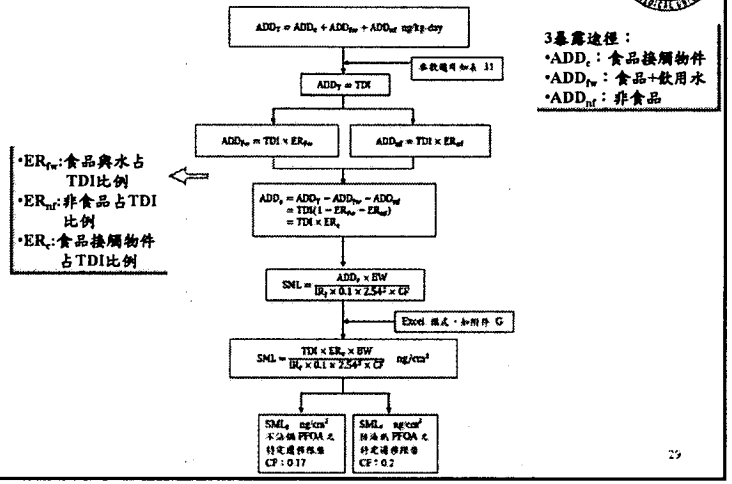
本研究防油紙高溫遷移試驗結果與品管執行情形

序號	樣品編號	遷移濃度(ng/g)[a]	遷移濃度 (ng/cm^2)[b]	RCSS (%)[c]	RPD (%)[d]
室溫甲醇					
9	O990810F	85.2	0.53	79.2	6.3
12	O990823C	183	0.99	89.8	0.9
13	O991123U	103	0.5	91.4	15.3
高溫模擬油					
9	O991123F	ND	ND	91.2	0.6
12	O991123E	ND	ND	91.5	2.1
13	O991123D	ND	ND	90.5	2.8
高溫模擬油→室溫甲醇					
9	O991123I	38.2	0.24	87.0	6.4
12	O991123H	63.1	0.34	83.6	1.0
13	O991123G	75.9	0.37	85.2	10.5



[a]檢出限量:0.2 ng/mL [b]遷移濃度(ng/cm²)以單面面積計算
[c]回收率要求60-110% [d]相對差異百分比要求<20%

PFOA之三路徑風險模式演算法



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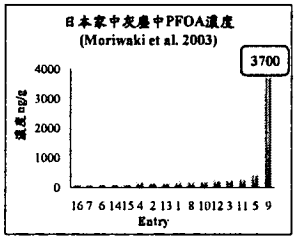
暴露情境設定之引用文獻

歐盟PFOA各路徑比例(EFSA, 2008)

	PFOA	PFOS
Food & Drinking water exposure	>50%	98%
Drinking water	<15% (3.4 mg/L)	<0.5% (0.6 mg/L)
Non-food	<50% Child much more (indoor)	Child much Less
Level in sea food	Lower	Higher (BCF=2000,50% decay 100 days)
Level in fish liver	Higher in liver than in fillet	
In environment	Widely found	



$$ER_{nf} = \frac{20\ (\frac{m^3}{d}) \times 300\ (\frac{\mu g}{m^3}) \times 4000\ (\frac{ng}{g}) \times \frac{1}{10^3}\ (\frac{g}{\mu g}) + 60\ (kg)}{1500\ ng/kg-d} \times 100 = 27\%$$

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PFOA風險評估之三種暴露情境之設定

低食物+水暴露情境A	中食物+水暴露情境B	高食物+水暴露情境C
• ER_{nf}：25%	• ER_{nf}：25%	• ER_{nf}：25%
• ER_{fw}：50%	• ER_{fw}：60%	• ER_{fw}：70%
• ER_c：25%	• ER_c：15%	• ER_c：5%

$$ER_{fw} = \frac{\overbrace{2000\ (\frac{g}{d}) \times 20\ (\frac{ng}{g})}^{ER_f:44\%} + \overbrace{1.5\ (\frac{L}{d}) \times 10000\ (\frac{ng}{L})}^{ER_w:17\%}}{60\ (kg)} \div 1500\ ^{ng}/_{kg-d} \times 100 = 61\%$$

$$ER_{nf} = \frac{20\ (\frac{m^3}{d}) \times 300\ (\frac{\mu g}{m^3}) \times 4000\ (\frac{ng}{g}) \times \frac{1}{10^3}\ (\frac{g}{\mu g}) \div 60\ (kg)}{1500\ ng/kg-d} \times 100 = 27\%$$

$$ER_c = 1 - ER_{fw} - ER_{nf}$$

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PFOA風險評估暴露參數之選用

TDI	歐盟訂定PFOA之值，1500 ng/kg-day *(EFSA,2008)*
ER_{fw}	食物與飲用水暴露路徑占總TDI之比例，保守情境下設定為50%、60%、70%。
ER_{nf}	非食品暴露路徑占總TDI之比例，於保守情境下的計算為25%。
ER_c	食品接觸物件占總TDI之比例。
CF	物件材質消費比例係數，不沾鍋0.17、防油紙0.2*(USFDA,2007)*
0.1	食品與物件材質接觸係數慣用值，10 g food/cm² *(USFDA,2007)*
2.54^2	in^2與cm^2單位轉換因子。
BW	體重，7-18歲：46.5 kg；19-59歲：64.5 kg；60+歲：62.0 kg。
IR_f	每日攝食率，7-18歲：2.2 g/d；19-59歲：2.3 g/d；60+歲：2.2 g/d。
	(BW與IR_f參考台灣一般民眾暴露參數彙編*(國健局, 2008)*)

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風險評估結果--不沾鍋PFOA特定遷移限值 (SML_p)

暴露族群	年齡 (yr)	體重[a] (BW, kg)	攝食率[b] (IR, kg/d)	物件材質消費比例係數(CF)	非食物暴露比例 (ER_{ab}, %)	每日耐受量(TDI, ng/kg-d)	食物+水暴露比例 (ER_{fw}, %)	特定遷移總值 SMLp (ng/cm²) P50	特定遷移總值 SMLp (ng/cm²) P95
							50	69.5	24.8
青少年	7-18	N(46.5,16.4)	N(2.20,0.65)	0.17[c]	27	1500[d]	60	39.0	13.7
							70	9.0	3.4
							50	84.4	18.3
成年人	19-59	N(64.5,41.1)	N(2.26,0.84)	0.17[c]	27	1500[d]	60	48.2	10.4
							70	11.2	2.4
							50	93.4	24.3
年長者	60+	N(62.0,29.6)	N(2.15,0.61)	0.17[c]	27	1500[d]	60	52.8	14.3
							70	12.2	3.3

[a,b] 2008年台灣一般民眾暴露參數彙編(國民健康局, 2008)

[c] 不沾鍋物件材質消費比例係數(USFDA, 2007)

[d] PFOA每人每日之耐受量(EFSA, 2008)

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風險評估結果--防油紙PFOA特定遷移限值 (SML_o)

暴露族群	年齡 (yr)	體重[a] (BW, kg)	攝食率[b] (IR, kg/d)	物件材質消費比例係數(CF)	非食物暴露比例 (ER_{ab}, %)	每日耐受量(TDI, ng/kg-d)	食物+水暴露比例 (ER_{fw}, %)	特定遷移總值 SMLo (ng/cm²) P50	特定遷移總值 SMLo (ng/cm²) P95
							50	58.9	20.9
青少年	7-18	N(46.5,16.4)	N(2.20,0.65)	0.2[c]	27	1500[d]	60	32.9	11.7
							70	7.6	2.7
							50	72.0	15.7
成年人	19-59	N(64.5,41.1)	N(2.26,0.84)	0.2[c]	27	1500[d]	60	40.7	8.6
							70	11.7	1.0
							50	79.5	22.1
年長者	60+	N(62.0,29.6)	N(2.15,0.61)	0.2[c]	27	1500[d]	60	44.7	12.6
							70	10.4	2.8

[a,b] 2008年台灣一般民眾暴露參數彙編(國民健康局, 2008)

[c] 防油紙物件材質消費比例係數(USFDA, 2007)

[d] PFOA每人每日之耐受量(EFSA, 2008)

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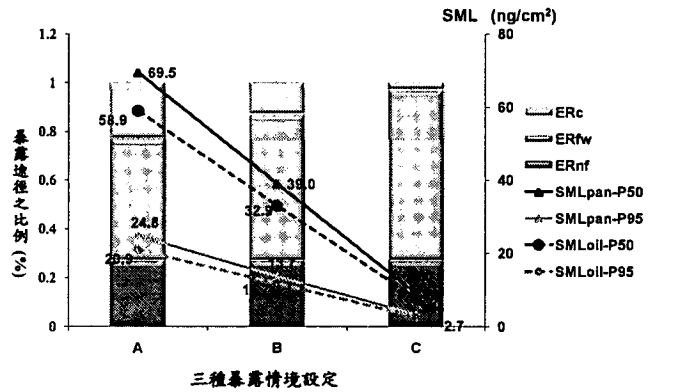
7-18歲各路徑劑量比例及不沾鍋與防油紙之特定遷移限值(SML)



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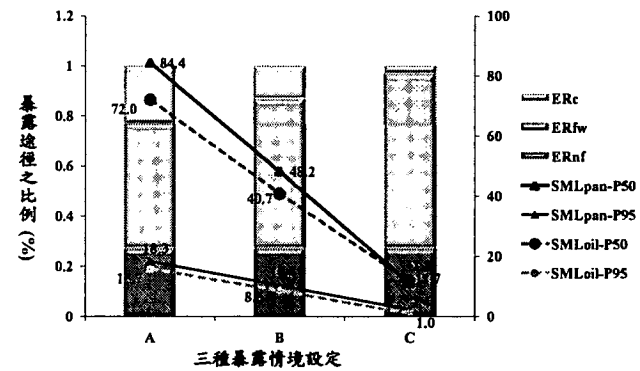
19-59歲各暴露途徑比例及不沾鍋與防油紙之特定遷移限值(SML)



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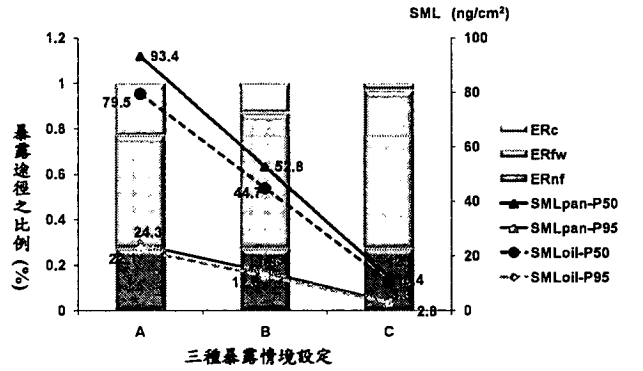
60+歲各暴露途徑比例及不沾鍋與防油紙之特定遷移限值(SML)



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SML建議值與歐盟與美國估算值之比較

管制單位/出處	管制限值	說明
本研究(2010)	• 不沾塗層鍋具 SML_p = 2.4 ng/cm² • 食品包裝防油紙 SML_o = 1.0 ng/cm²	• 三個年齡層7-18 yr, 19-59 yr, 60+ yr，其中19-59 yr為最易感族群。 • 最大化ER_{nf} = 27%及ER_{fw} = 50, 60, 70%。 • 引用USFDA(2007)之CF,不沾鍋具為0.17，防油紙為0.2。 • 使用我國暴露參數：BW,IR_f。 • 進行Monte Carlo分析，以SML之P95值為管制限值。
European Union (2006), Directive 2006/122/ECOF	• 針對紡織品及其他物件塗層之PFOS含量需<0.1 ng/cm² • 推估PFOA含量管制限值為1 ng/cm²	• PFOA之TDI為PFOS之10倍，所以PFOA之管制限制可推估為PFOS之10倍。
European Union, Directive EC/1935/2004 EUROPA>EC>DG Health and Consumers 網站資料庫	• OML = DCL = 60 mg/kg food • 尚未訂定PFOA管制限值 (2010.12.04上網查詢)	• 為Website資料庫，供食品業者申請FCM之用，目前共管制17大類853種FCM，PFOA屬於Plastics (9)之Additives (9.1)。 • 假設IR=1 kg/d, BW=60 kg, S/V = 6 dm²/kg。
Office of Food Additive Safety (OFAS) CEDI/ADI 網站資料庫	• PFOA管制限值：DCL=0.12 ppb (ug/kg), CEDI= 6 ng/kg-day • SML=(6 ng/kg-d)(60 kg) (1/3000 d/g)(10 g/in²)(1 in/2.54 cm)² = 0.2 ng/cm²	• 為Website資料庫，供食品業者申請FCS之用，目前共管制1267種FCS。 • 假設IR = 3 kg/d, BW = 60 kg, S/V = in²/10 g。

結論一室溫及高溫遷移

- 本研究建立PFOA室溫及高溫遷移試驗方法及HPLC/MS/MS之定量分析方法，可以符合USFDA (2007)品管基準：全程RCSS之Recovery為60~110%及RPD<20%；上機液LOQ=0.2 ng/mL (0.004~0.068 ng/cm²)
- 室溫甲醇試驗結果：不沾鍋ND~0.021 ng/cm² (n=15)，防油紙ND~0.99 ng/cm² (n=15)。
- 高溫模擬油試驗結果：不沾鍋 ND (n=3)，防油紙ND(n=3)，即使在高溫(100~125°C)，PFOA不易於模擬之大豆沙拉油中溶出。
- 高溫模擬油→室溫甲醇試驗結果：不沾鍋 ND~0.0078 ng/cm² (n=3)，防油紙 0.24~0.37 ng/cm² (n=3)，說明再溶出之可能。

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結論一健康風險評估

- 本研究建立一個三暴露途徑之風險評估模式，將食品+飲用水(ER_{fw})以及非食品(ER_{nf})暴露途徑，以保守情境估算二者占總TDI之最大比例：ER_{nf}為27%；ER_{fw}為50%、60%、70%。
- 因CF參數之不同，比較三組暴露族群之不沾鍋與防油紙之SML，防油紙皆低於不沾鍋(防油紙CF為0.2，不沾鍋CF為0.17)。
- 於保守情境下，三組暴露族群中，因BW與IR的差異，「7-18歲青少年」有最低P50之SML；而「19-59歲成年人」 有最低P95之SML。
- 建議我國不沾鍋及防油紙之PFOA之SML_p=2.4 ng/cm²，SML_o=1.0 ng/cm²。
- 本研究所有常溫甲醇及高溫模擬試驗結果均未超過此建議限值。
- 推估歐盟(EU, 2006)之塗層物件PFOA管制限值為1 ng/cm²，美國(USFDA, 2007)之食品PFOA暴露管制限值為0.2 ng/cm²，本研究模擬結果與歐盟推估值相當。

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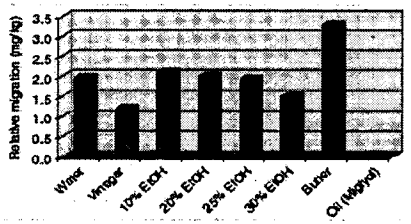
建議

- 我國FCS管制：較偏向歐盟方法，建議釐清現行辦法之：遷移濃度計算方法、溶媒體積、暴露面積、管制標準等議題。
- 一般認為食品接觸物件PFOA的風險甚低，但在國人特殊高溫烹煮條件下(油+離子/非離子性物質)，是否會成為重要暴露來源，應進一步釐清。
- 建議針對PFOS，調查肉類、乳製品及水產食物之PFOS含量，並進行健康風險評估。
- 建議逐年調查國人血液中PFOA及PFOS之濃度，了解其濃度變化趨勢。



防油紙全氟辛烷磷酸(PFOP)於各類模擬物100 °C/15 min遷移量(Begley et al., 2008)

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