5/index.htm.
7. Nakanishi J., Tsunemi K., 2008. *Short chain chlorinated paraffins*; AIST risk assessment document series No. 6, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan; http://unit.aist.go.jp/riss/crm/mainmenu/1-9.html.
8. NBS, 2009. *China industry economy statistical yearbook 2009.* Department of Industrial and Tranportation Statistics, National Breau of Statistics of the People's Republic of China, China Statistics Press, Beijing, China.
9. Niisoe T., Harada K.H., Ishikawa H., Koizumi A., 2010. Long-term simulation of human exposure to atmospheric perfluorooctanoic acid (PFOA) and perfluorooctanoate (PFO) in the Osaka urban area, Japan, *Environ. Sci. Technol. 44*, 7852-7857.
10. Onogi K., Tsutsui J., Koide H., Sakamoto M., Kobayashi S, Hatsushika H., Matsumoto T., Yamazaki N., Kamahori H., Takahashi K., Kodokura S., Wada K., Kato K., Oyama R., Ose T., Mannoji N., Taira R., 2007. The JRA-25 reanalysis, *J. Meteorol. Soc. Jpn. 85*, 369-432.
11. Peters A.J., Tomy G.T., Jones K.C., Coleman P., Stern G.A., 2000. Occurrence of C_{10}-C_{13} polychlorinated n-alkanes in the atmosphere of the United Kingdom. Atmos. Environ., 34, 3085-3090.
12. Wang Y., Fu J., Jiang G., 2009. The research of environmental pollutions and toxic effect of short chain chlorinated paraffins, *Environ. Chem. 28*, 1-9 (in Chinese).
13. Zeng L., Wang T., Han W., Yuan B., Liu Q., Wang Y., Jiang G., 2011. Spatial and vertical distribution of short chain chlorinated paraffins in soils from wastewater irrigated farmlands, *Environ. Sci. Technol. 45,* 2100-2106.
14. Zeng L., Wang T., Ruan T., Liu Q., Wang Y., Jiang G., 2012. Levels and distribution patterns of short chain chlorinated paraffins in sewage sludge of wastewater treatment plants in China, *Environ. Pollut., 160,* 88-94

表 1　2011年の関西における大気中SCCPs濃度（ng m^{-3}）の測定値とモデルによる計算値。

測定点	測定日	日平均濃度 (ng m^{-3})	計算値 (ng m^{-3})
京都市左京区	2011/01/24	2.81	7.85
(Yoshida)	2011/01/25	4.05	2.16
	2011/01/26	1.80	1.82
	2011/01/27	1.64	1.90
	2011/01/28	1.90	1.16
	2011/01/29	2.58	0.91
	2011/01/30	4.89	0.60
	幾何平均値	2.60	1.68
京都市伏見区	2011/02/10	0.57	1.30
(Ujigawa)	2011/02/11	1.93	0.63
	2011/02/12	1.73	0.67
	2011/02/13	7.47	1.21
	2011/02/14	13.7	0.57
	2011/02/15	3.26	0.83
	2011/02/16	2.99	0.95
	幾何平均値	2.94	0.84
尼崎市	2011/02/25	3.35	3.88
(Amagasaki)	2011/02/26	2.99	0.42
	2011/02/27	9.14	1.34
	2011/02/28	8.37	0.78
	2011/03/01	4.85	1.70
	2011/03/02	2.15	1.57
	2011/03/03	2.90	0.69
	幾何平均値	4.20	1.18
柏原市	2011/03/11	2.51	3.04
(Kashiwara)	2011/03/12	9.83	2.20
	2011/03/13	2.79	1.59
	2011/03/14	1.91	2.57
	2011/03/15	0.963	7.33
	幾何平均値	2.63	2.88
釜山市	2008/12/14	3.78	3.61
(Busan)	2008/12/15	7.25	10.5
	2008/12/16	6.11	6.73
	幾何平均値	5.51	6.34
北京市	2008/10/18	242	282
(Beijing)	2008/10/19	166	235
	2008/10/19	348	269
	2008/10/20	190	280
	幾何平均値	227	266

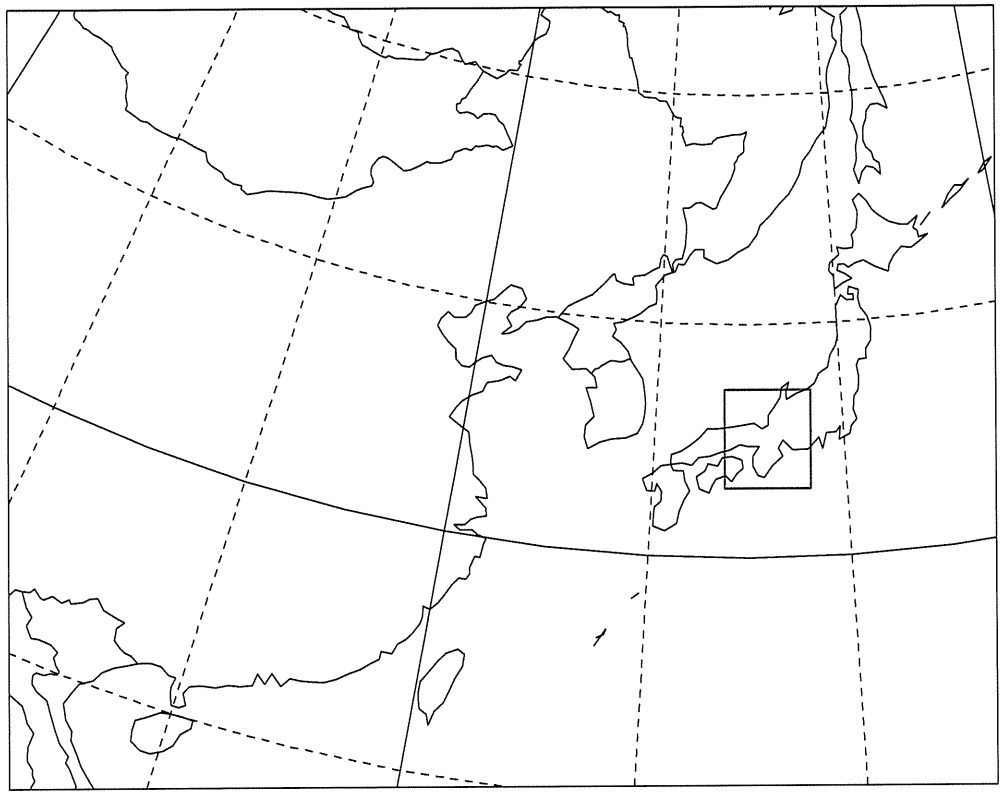

図 1　計算領域。東西 4500km、南北 3600km、水平解像度 90km の領域 1（黒枠）と、東西南北 450km、水平解像度 9km の領域 2（赤枠）を結合した。

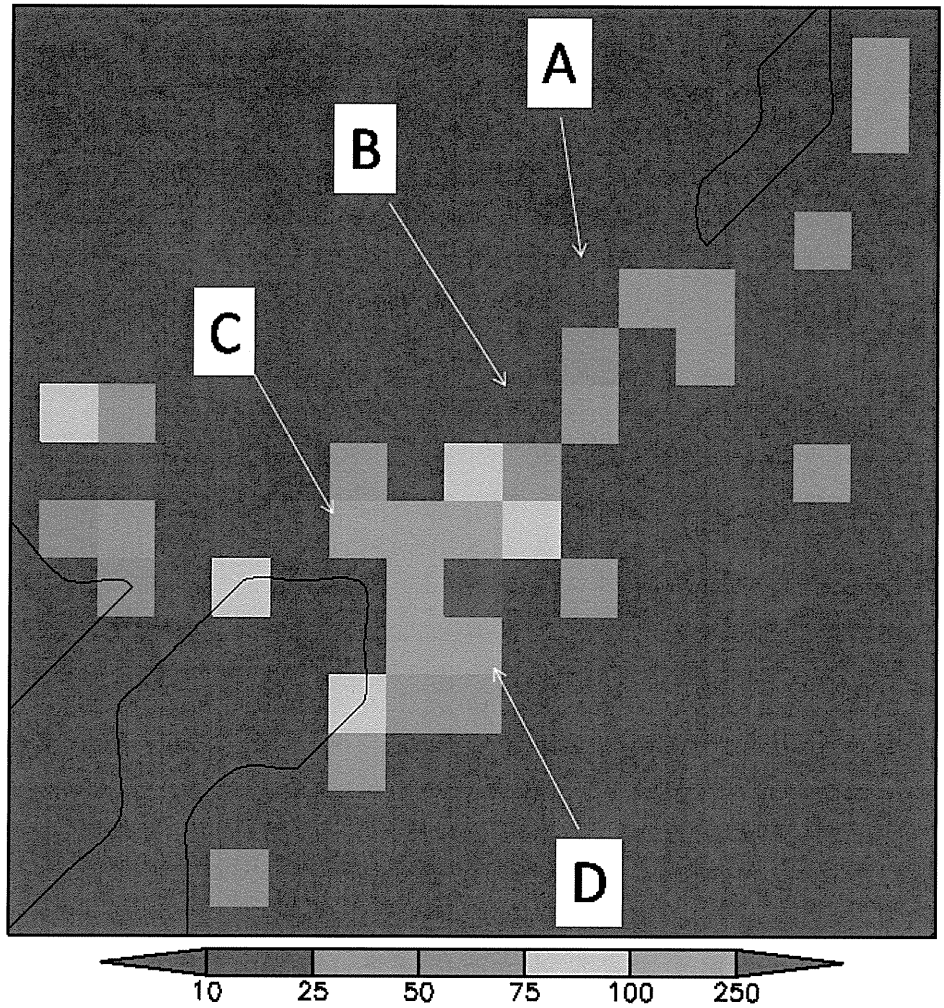

図 2　2006年の関西における大気へのSCCPs排出量の推定分布(μg m^{-2} yr^{-1})。A: Yoshida、B: Ujigawa、C: Amagasaki、D: Kashiwara。最も高いグリッドは東大阪市。

図 3　ハイボリュームエアサンプラー設置の様子。2011 年 2 月 10 日京都大学防災研究所宇治川オープンラボラトリー構内（Ujigawa）。

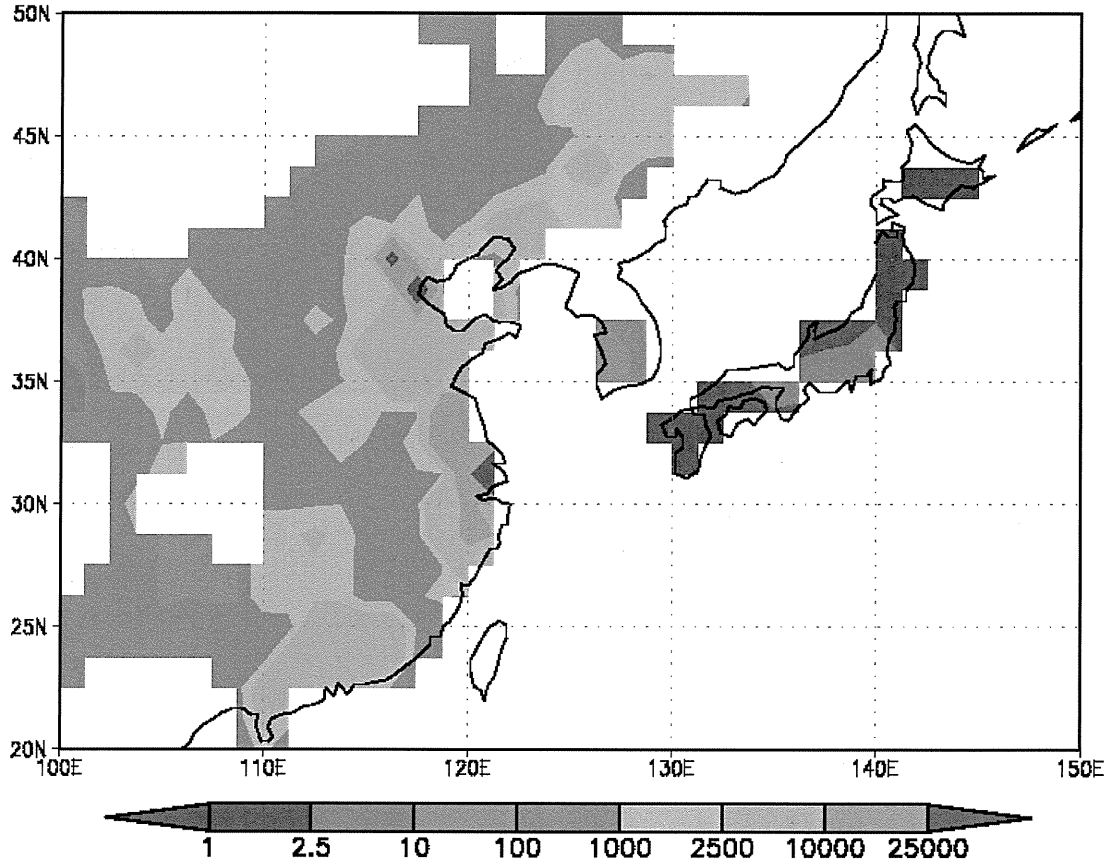

図 4　日本、韓国、中国における大気への SCCPs 推定排出分布。国ごとの排出量はそれぞれ 1.1 t yr^{-1}、14 t yr^{-1}、12000 t yr^{-1}。

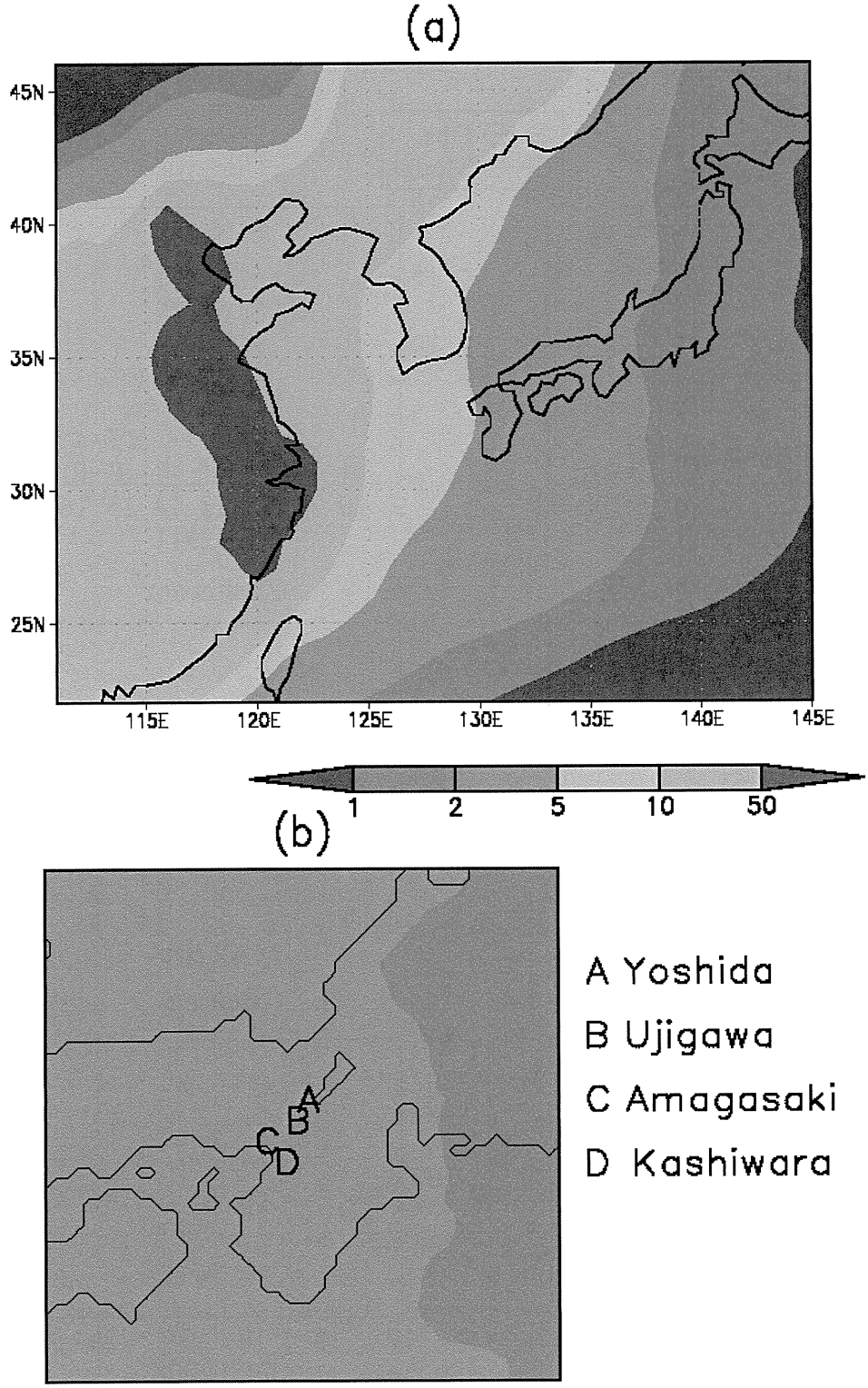

図 5　2011 年 2 月における地表付近の大気中 SCCPs の月平均濃度分布の計算結果(ng m^{-3})。(a)計算領域 1、(b)計算領域 2。Yoshida、Ujigawa、Amagasaki、Kashiwara を含む西日本全体が 2～5 ng m^{-3} の領域にある。

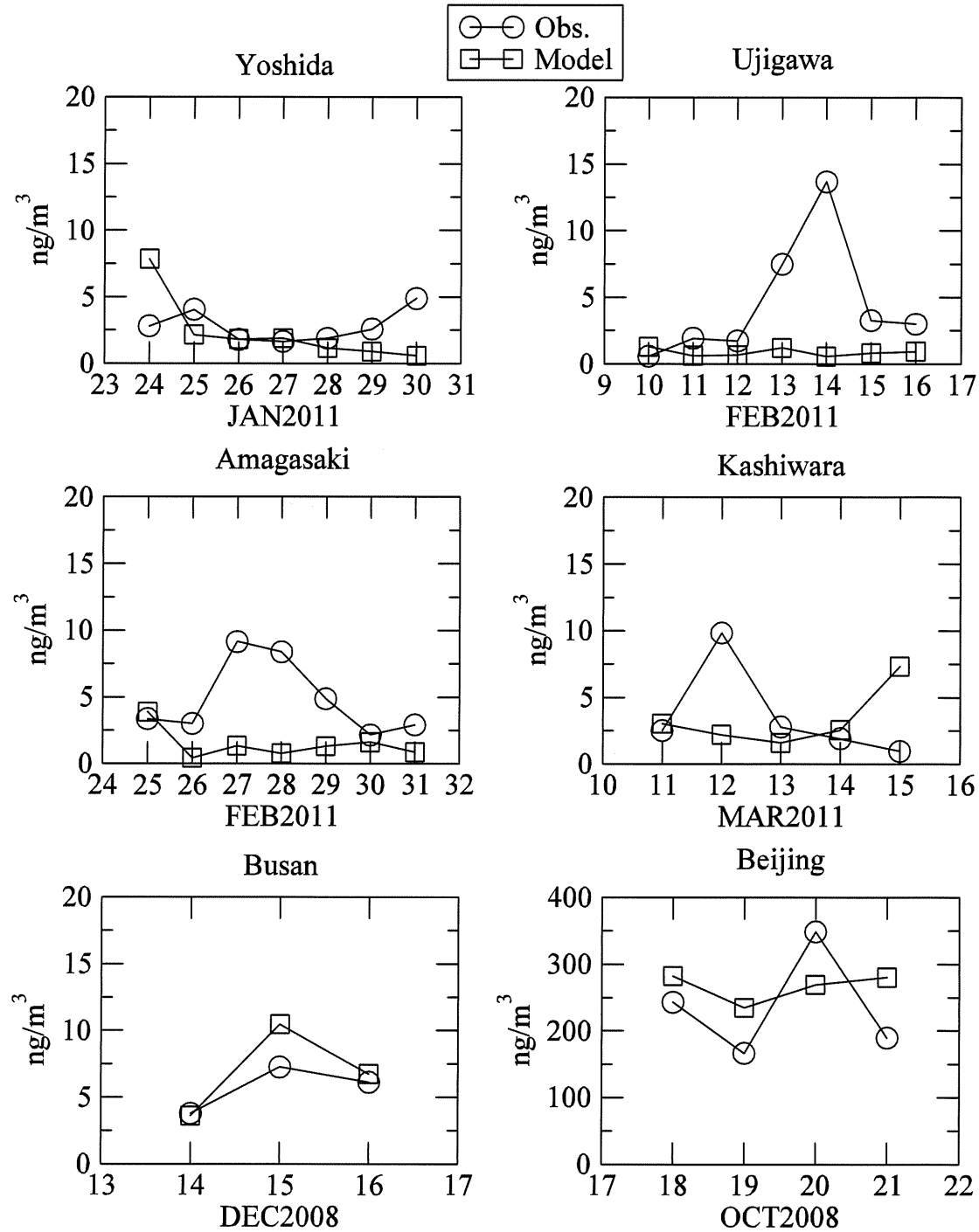

図 6　大気中 SCCPs 濃度の日平均値 (ng m^{-3}) の計算結果 (□) と実測結果 (○) との比較。

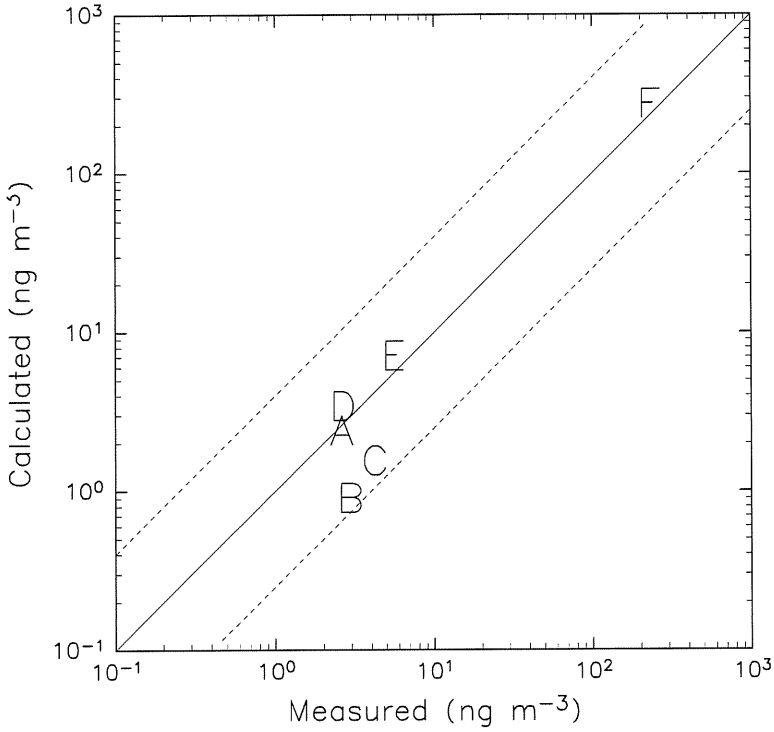

図 7　地表面大気中 SCCPs 濃度（ng m^{-3}）の計算値と実測値との比較。破線は factor 4 の誤差を表す。A: Yoshida、B: Ujigawa、C: Amagasaki、D: Kashiwara、E: Busan、 F: Beijing。

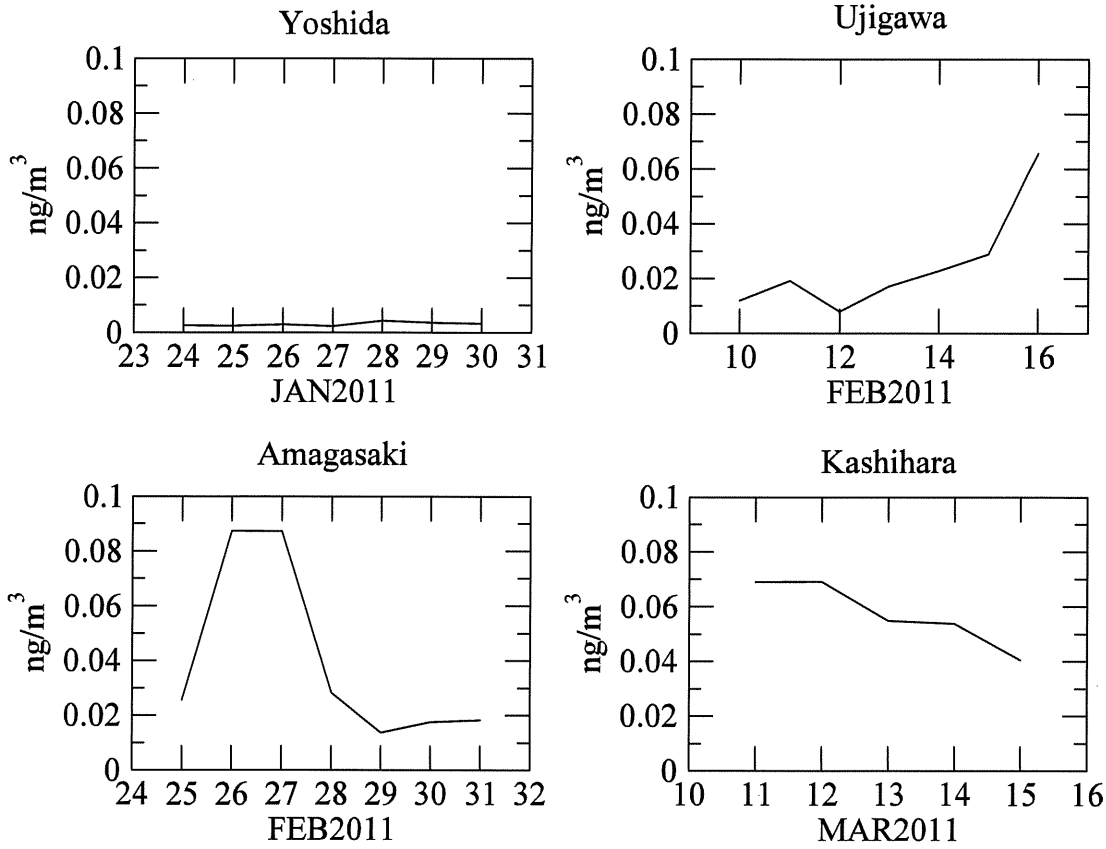

図 8　日本における排出のみをモデルに与えた場合の関西４地点における大気中濃度の計算結果（ng m^{-3}）。

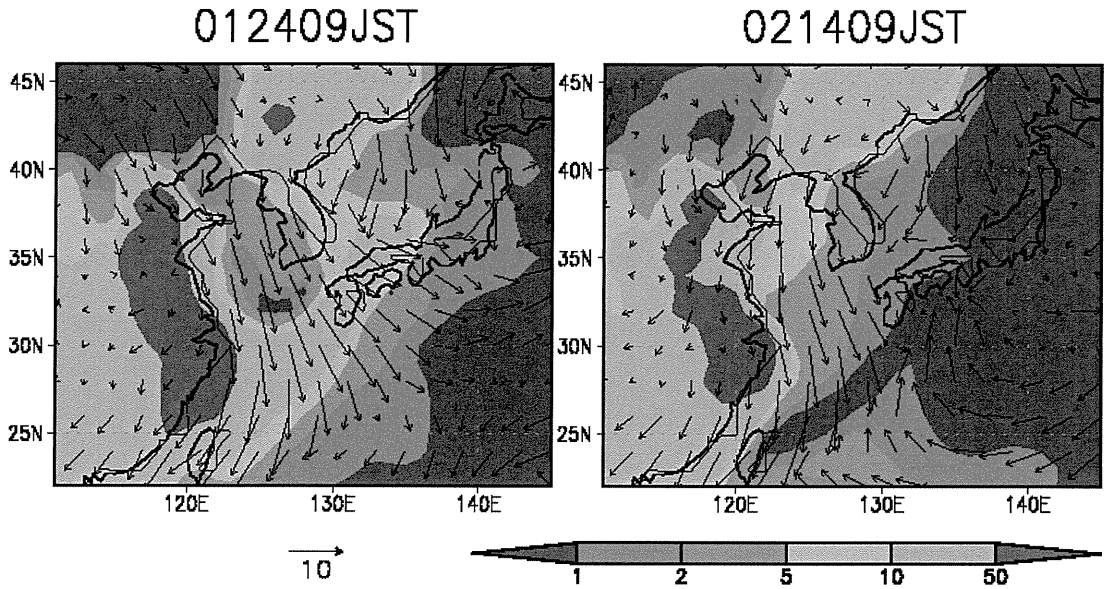

図 9　2011年1月24日および2月14日午前9時における地表面大気中SCCPs濃度分布（ng m^{-3}）と風速場（m s^{-1}）。1月24日は高気圧、2月14日は低気圧が日本の上空にあった。

厚生労働科学研究費補助金(食品の安全確保推進研究事業)
分担研究報告書

食の安全のための国際協力とリスクコミュニケーション

研究代表者 小泉　昭夫　京都大学医学研究科

研究要旨
「生体試料バンクを有効活用した食の安全と安心の基盤形成」ではモニタリング手法の開発、汚染物質調査、データベース構築、系統的試料の収集とならび、国際協力とリスクコミュニケーションは重要な課題の一つである。
今年度は昨年度の調査で判明した中国での短鎖塩素化パラフィンの歴史的な増加、油脂類の汚染、さらに日本でも輸入された油脂に含まれることを明らかにしている。また大気を通じた越境汚染の問題も明らかになっている。
そこで、専門家である北京大学公衆衛生院王培玉教授への情報提供、情報交換、韓国での環境衛生専門家のフォーラムでの議論のほか、メディアを通じた注意喚起を行った。

A. 研究目的

平成22年度厚生労働科学研究費補助金食品の安心・安全確保推進研究事業「生体試料バンクを有効活用した食の安全と安心の基盤形成」では日中韓での食品、母乳を介した化学物質の曝露状況を明らかにした。

各国の汚染のプロファイルの違いや、経年的変化もそれぞれでことなり、この情報を今後の対策に活かすことが必要である。

B. 研究方法

中国での短鎖塩素化パラフィンの歴史的な増加、油脂類の汚染、さらに日本でも輸入された油脂に含まれることを明らかにしている。また大気を通じた越境汚染の問題も明らかになっている。

そこで、専門家である北京大学公衆衛生院王培玉教授への情報提供、情報交換を行った。

韓国での環境衛生専門家のフォーラムInternational Forum for Environment Health Policy and Science(2011年11月25日　Seoul National University)で越境汚染への対策と国際協力のあり方について議論を行った。国内の母乳哺育推進団体へこれまでの成果を報告するとともに、育児に影響を与えないようなリスクコミュニケーションのあり方を検討した。またメディアを通じた注意喚起を行った。

C. 結果と考察

輸入食品の問題は日中韓で大きな問題として捉えられている。輸出国としても品質への信頼が重要である。各国の情報交換により対象となる化学物質、農薬を明確にしていくことが求められた。特に越境汚染の問題では相手国の情報を正しく知る必要があり、緊密な連携が不可欠であるという共通理解があった。

フォーラムでの有識者、市民の意見を尊重して、その精神を試料バンク運営に反映させたいと考えている。

研究の成果について報道各社を通じて公開した。

D. 結論

国際協力とリスクコミュニケーションのために意見交換を行い、フォーラムでの議論を行い、所定の成果を得られた。

E. 健康危険情報

なし

F. 研究発表

1. 論文発表

Kyungho Choi, Domyung Paek, Tangchun Wu, Chang-Chuan Chan, Rattapon Onchang, Chantana Padungtod, Akio Koizumi
Asian forum on environmental health policy: challenges and perspectives of environmental health problems in the region in the next 30 years
Environ Health Prev Med, 17(2): 170-172, Feb 2012 doi: 10.1007/s12199-012-0269-7

2. 学会発表・その他

小泉昭夫・Cooperative ways to solve transboundary environmental problems in Asian, International Forum for Environment Health Policy and Science, 2011年11月25日 Seoul National University

小泉昭夫, 環境汚染物質のモニタリングと今後の課題－母乳の安心・安全－, 第26回 日本母乳哺育学会・学術集会, 2011年10月8-9日 日本赤十字社医療センター

2011年 11月16日 朝日新聞(11月15日 5面)「内部被曝は限度以下 福島原発周辺京大などが推計」、京都新聞(11月15日 30面)、日本経済新聞(11月15日夕刊 15面)「福島在住成人の内部被曝「気にする水準でない」 京大が調査」および毎日新聞(11月15日 27面)、福島中央テレビ(11月15日)「セシウム摂取量を調査 基準を大きく下回る」

2011年7月15日 京都新聞「中国の食用油に発がん疑い物質 京大教授らが調査」

2011年7月14日 日本放送協会 (京都)「中国の油から工業用成分検出」

G. 知的財産権の出願・登録状況
(予定を含む)

1. 特許取得・実用新案登録

なし

別紙４

研究成果の刊行に関する一覧表

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
Desalegn B, Nanayakkara S, Harada KH, Hitomi T, Chandrajith R, Karunaratne U, Abeysekera T, Koizumi A.	Mycotoxin detection in urine samples from patients with chronic kidney disease of uncertain etiology in Sri Lanka.	Bull Environ Contam Toxicol	87	6-10	2011
Desalegn B, Takasuga T, Harada KH, Hitomi T, Fujii Y, Yang HR, Wang P, Senevirathna S, Koizumi A.	Historical trends in human dietary intakes of endosulfan and toxaphene in China, Korea and Japan.	Chemosphere	83	1398-405	2011
Fujii Y, Haraguchi K, Harada KH, Hitomi T, Inoue K, Itoh Y, Watanabe T, Takenaka K, Uehara S, Yang HR, Kim MY, Moon CS, Kim HS, Wang P, Liu A, Hung NN, Koizumi A.	Detection of dicofol and related pesticides in human breast milk from China, Korea and Japan.	Chemosphere	82	25-31	2011
Fujii Y, Ito Y, Harada KH, Hitomi T, Koizumi A, Haraguchi K	Regional variation and possible sources of brominated contaminants in breast milk from Japan	Environ Pollut	162	269-74	2012
Fujii Y, Yan J, Harada KH, Hitomi T, Yang H, Wang P, Koizumi A	Levels and profiles of long-chain perfluorinated carboxylic acids in human breast milk and infant formulas in East Asia	Chemosphere	86	315-21	2012
Harada KH, Hitomi T, Niisoe T, Takanaka K, Kamiyama S, Watanabe T, Moon CS, Yang HR, Hung NN, Koizumi A	Odd-numbered perfluorocarboxylates predominate over perfluorooctanoic acid in serum samples from Japan, Korea and Vietnam	Environ Int	37	1183-9	2011
Harada KH, Takasuga T, Hitomi T, Wang P, Matsukami H, Koizumi A	Dietary exposure to short-chain chlorinated paraffins has increased in beijing, china	Environ Sci Technol	45	7019-27	2011
Haraguchi K, Kato Y, Ohta C, Koga N, Endo T	Marine sponge: a potential source for methoxylated polybrominated diphenyl ethers in the Asia-Pacific food web	J Agric Food Chem	59	13102-9	2011
Koizumi A, Harada KH, Niisoe T, Adachi A, Fujii Y, Hitomi T, Kobayashi H, Wada Y, Watanabe T,	Preliminary assessment of ecological exposure of adult residents in Fukushima Prefecture to	Environ Health Prev Med			2012

Ishikawa H	radioactive cesium through ingestion and inhalation				
Kyungho Choi, Domyung Paek, Tangchun Wu, Chang-Chuan Chan, Rattapon Onchang, Chantana Padungtod, Akio Koizumi	Asian forum on environmental health policy: challenges and perspectives of environmental health problems in the region in the next 30 years	Environ Health Prev Med	17	170-172	2012
Liu W, Chen S, Harada KH, Koizumi A	Analysis of perfluoroalkyl carboxylates in vacuum cleaner dust samples in Japan	Chemosphere	85	1734-41	2011
Niisoe T, Harada KH, Hitomi T, Watanabe T, Hung NN, Ishikawa H, Wang Z, Koizumi A	Environmental ecological modeling of human blood lead levels in East Asia	Environ Sci Technol	45	2856-62	2011
Endo T, Hotta Y, Hisamichi Y, Kimura O, Sato R, Haraguchi K, Funahashi N, Baker CS	Stable isotope ratios and mercury levels in red meat products from baleen whales sold in Japanese markets	Ecotoxicology and Environmental Safety	79	35-41	2012
Hayasaki M, Yamamoto MK, Higuchi A, Shimizu A, Mori I, Nishikawa M, Takasuga T	Asian Dust Transport to Kanto by Flow around Japan's Central Mountains	SOLA	7A	32-5	2011
Hisamichi Y, Haraguchi K, Endo T	Levels of mercury and organohalogen compounds in Pacific bluefin tuna (Thunnus orientalis) cultured in different regions of Japan	Arch Environ Contam Toxicol	62	296-305	2012
Kato Y, Onishi M, Haraguchi K, Ikushiro S, Ohta C, Koga N, Endo T, Yamada S, Degawa M	A possible mechanism for 2,2',4,4',5,5'-hexachlorobiphenyl-mediated decrease in serum thyroxine level in mice	Toxicology and Applied Pharmacology	254	48-55	2011
Kimura O, Kotaki Y, Hamaue N, Haraguchi K, Endo T	Transcellular transport of domoic acid across intestinal Caco-2 cell monolayers	Food Chem Toxicol	49	2167-71	2011
Koga N, Ohta C, Kato Y, Haraguchi K, Endo T, Ogawa K, Ohta H, Yano M	In vitro metabolism of nobiletin, a polymethoxy-flavonoid, by human liver microsomes and cytochrome P450	Xenobiotica	41	927-33	2011
Mori I, Nishikawa M, Shimizu A, Hayasaki M, Takasuga T	Solubility of Iron in the Aerosol Collected during Kosa (Asian Dust) Events in Japan	SOLA	7A	5-8	2011
Romero MLJ, Kotaki Y, Lundholm N, Thoha H,	Unique amnesic shellfish toxin composition found in	Harmful Algae	10	456-62	2011

Ogawa H, Relox JR, Terada R, Takeda S, Takata Y, Haraguchi K, Endo T, Lim P-T, Kodama M, Fukuyo Y	the South East Asian diatom Nitzschia navis-varingica				
小泉昭夫、藤井由希子、新添多聞、原田浩二	日中韓における母乳を用いた残留性有機汚染物質のモニタリング	日本母乳哺育学会雑誌	5	41-52	2012
新添多聞、原田浩二、小泉昭夫	コンピューターシミュレーションによる環境中化学物質のヒト曝露評価法,	日本公衆衛生雑誌	58 巻	209-211	2011
太田千穂, 原口浩一, 加藤善久, 遠藤哲也, 古賀信幸	【油症と PCB 及びダイオキシン関連化合物に関する研究 報告集 第23集】2、2'、3、4、4'、5'-六塩素化ビフェニル(CB138)のモルモットにおける in vivo 代謝	福岡医学雑誌	102 巻	167-174	2011

Chemosphere 83 (2011) 1398–1405

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Historical trends in human dietary intakes of endosulfan and toxaphene in China, Korea and Japan

Biruck Desalegn [a], Takumi Takasuga [b], Kouji H. Harada [a], Toshiaki Hitomi [a], Yukiko Fujii [a], Hye-Ran Yang [a], Peiyu Wang [c], STMLD Senevirathna [a], Akio Koizumi [a,*]

[a] Department of Health and Environmental Sciences, Graduate School of Medicine, Kyoto University, Yoshida, Kyoto 606-8501, Japan
[b] Shimadzu Techno-Research Inc., Nishinokyo, Kyoto 604-8436, Japan
[c] Department of Social Medicine and Health Education, School of Public Health, Peking University, Haidian, Beijing 100083, PR China

ARTICLE INFO

Article history:
Received 28 October 2010
Received in revised form 14 January 2011
Accepted 27 February 2011
Available online 5 April 2011

Keywords:
Endosulfan
Toxaphene
Food duplicate
China
Japan
Korea

ABSTRACT

Recently, the Stockholm Convention prohibited the use of toxaphene and has been reviewing endosulfan. The historical use of these pesticides may contaminate food and tend to accumulate in the food chain. In this study, to evaluate the spatial and temporal trends of food contamination, the endosulfan and toxaphene levels were measured in pooled 24-h food composite samples from Chinese ($n = 10$), Korean ($n = 10$) and Japanese ($n = 40$) adults in the 1990s and 2007–2009. Endosulfan was detected in 32 of 40 samples from Japan, but its levels (sum of α- and β-isomers) were low in both the 1990s and 2009 (range as geometric mean (geometric standard deviation) [GM (GSD)]: 0.96 (1.6)–1.42 (1.4) ng kg^{-1} d^{-1}). The dietary intakes of endosulfan in Seoul as GM (GSD) were 38.68 (1.3) ng kg bw^{-1} d^{-1} in 1994 and 92.17 (4.4) ng kg bw^{-1} d^{-1} in 2007, and significantly higher than those in Japan ($p < 0.05$). The samples from Beijing showed a 50-fold increase in the endosulfan levels from 1993 (GM: 0.58 ng kg^{-1} d^{-1}) to 2009 (GM: 24.91 ng kg bw^{-1} d^{-1}) ($p < 0.05$). Toxaphene was detected in 33 of 40 samples from Japan. The dietary intake of toxaphene in Japan (sum of Parlars #26, #50 and #62) was 0.32–1.21 ng kg bw^{-1} d^{-1} (range as geometric mean) and no temporal trend was observed. The dietary intake of toxaphene in Seoul increased significantly from 0.2 ng kg bw^{-1} d^{-1} (GM) in 1994 to 3.6 ng kg bw^{-1} d^{-1} (GM) in 2007 ($p < 0.05$). Only one of 10 pooled samples from Beijing contained a detectable level of toxaphene (0.3 ng kg bw^{-1} d^{-1}). For the entire population, the risk of adverse health effects from dietary intakes of endosulfan and toxaphene is unlikely. However, the concentrations of endosulfan in several samples exceeded 10% of the acceptable daily intake limit value of 6 μg kg bw^{-1} d^{-1} set by the World Health Organization (WHO). It appears important to refine dietary intake estimates targeting food types and source identification to ensure safe food for consumers.

1. Introduction

Non-occupational human exposure to organochlorine pesticides is mainly attributed to past and present consumption of foods contaminated by these chemicals (Dougherty et al., 2000; Jiang et al., 2005; WHO, 2005; Boobis et al., 2008). In real time, chronic exposure to these chemical contaminants and their potential subtle health effects as a consequence may not be noticed. Endosulfan (6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methylene-2,3,4-benzodioxathiepin-3-oxide) and toxaphene (polychlorinated 2,2-dimethyl-3-methylenebicyclo[2,2,1]heptane) are notable examples of organochlorine pesticides classified by the WHO and the United States Environmental Protection Agency (USEPA) as priority pollutants (Keith and Telliard, 1979). These chemicals occur in many environmental compartments and accumulate through the food chain owing to their persistence and semi-volatility (Saleh and Casida, 1978; ATSDR, 1990, 1991; Burgoyne and Hites, 1993; Weber et al., 2009).

The widespread use of endosulfan as an insecticide around the world (approximately 409 000 metric tons from 1946 to 1974), with technical formulations of α and β-isomers, has been reported (Matolcsy et al., 1988; Weber et al., 2009). Agricultural use of endosulfan in Japan started in 1960 and the total shipping volume of endosulfan from 2003 to 2007 was about 80 tons (POPRC, 2009). An inventory report by Jia et al. (2009) documented that 25 700 tons of endosulfan was used in China from 1994 to 2004 (Jia et al., 2009). Likewise, widespread environmental contamination by this chemical has been reported in China (Li et al., 2007), South Korea (Yeo et al., 2003) and urban Seoul (Yeo et al., 2004).

* Corresponding author. Address: Department of Health and Environmental Sciences, Graduate School of Medicine, Kyoto University, Yoshida Konoe, Sakyo, Kyoto 606-8501, Japan. Tel.: +81 75 753 4456; fax: +81 75 753 4458.
E-mail address: koizumi.akio.5v@kyoto-u.ac.jp (A. Koizumi).

0045-6535/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.chemosphere.2011.02.063

Guo et al. (2007) reported the exposure levels to this chemical via seafood products in China (Guo et al., 2007).

Toxaphene is a complex mixture of polychlorinated monoterpenes and was the most heavily used insecticide to replace DDT (Saleh and Casida, 1978). More than 1.3 million tons of toxaphene have been applied throughout the world (Oehme et al., 1996). A report on toxaphene practice indicated that this pesticide was registered in Korea (Wong et al., 2005) and China (de Geus et al., 1999). Although toxaphene has never been registered as a pesticide in Japan (Imanishi et al., 2005; Takazawa et al., 2007). Takazawa et al. (2007) hypothesized about the potential spread of this chemical in Far Eastern Countries including Japan. While the possibility of high-level contamination of toxaphene is low, since it is no longer used, there is a concern regarding health hazards attributable to long-term exposure to low levels of this chemical (ATSDR, 1996; Tryphonas et al., 2000).

Although countries differ in their histories of pesticide production, application and regulation, more importantly, changes in the consumption patterns and the growing international trades in food track these chemicals that could challenge global food safety. Owing to these possible changes in exposure to these chemicals over time, the temporal and regional variations in dietary residue levels need to be investigated. To the best of our knowledge, there are no documented studies assessing the historical trends of these chemicals in China, Korea and Japan. The present study estimated the trends of the dietary intakes of endosulfan and toxaphene in adult populations from these selected countries across specified time periods.

2. Materials and methods

2.1. Food sampling and preparation

The Ethics Committee of Kyoto University approved this study and appropriate written informed consent was obtained from all the research participants. Food samples from the Kyoto University Human Specimen Bank (Koizumi et al., 2005, 2009) were used for the analyses.

A total of 200 duplicate 24-h food samples were collected from Hokkaido in 1992 and 1995, Okinawa in 1992 and 1995, Kyoto in 1996 and 1997, Beijing in 1993 and 2009 and Seoul in 1994 and 2007 (Ikeda et al., 2000; Koizumi et al., 2009). Women participants were selected purposively to examine implication for future generation. In addition, for the 2009 samples in Japan, for practical reason, a 100-d meal and water supply was purchased by volunteers from markets in Kyoto, Okinawa and Hokkaido owing to the difficulty of finding individuals who often do not consume food away from home. From the total of 300 homogenized composite food samples, randomly selected five samples (30 g of each) were then pooled into 60 samples, as illustrated in Fig. 1. Therefore, the food samples from five subjects were treated as one pooled sample weighing 150 g. The samples were stored in a glass bottles at −30 °C until analysis.

2.2. Chemicals

The analytes investigated were α-endosulfan, β-endosulfan and toxaphene Parlars #26, #50 and #62 (Supelco Inc., Bellefonte, PA). $^{13}C_9$-α-endosulfan and $^{13}C_9$-β-endosulfan (Cambridge Isotope Laboratories, Andover, MA) were used as internal standards for α-endosulfan and β-endosulfan, respectively. $^{13}C_{10}$-trans-chlordane (Cambridge Isotope Laboratories) was used as the internal standard for toxaphene. $^{13}C_{12}$-2,2′,3,3′,5,5′,6-heptachlorobiphenyl and $^{13}C_{12}$-2,3,3′,5,5′-pentachlorobiphenyl (Cambridge Isotope laboratories) were used to monitor the recovery of the internal standards for endosulfan and toxaphene, respectively. Acetone, hexane, dichloromethane and sodium sulfate were purchased from Kanto Chemical Co. Inc. (Reagents and solvents for residual pesticides test and PCB test).

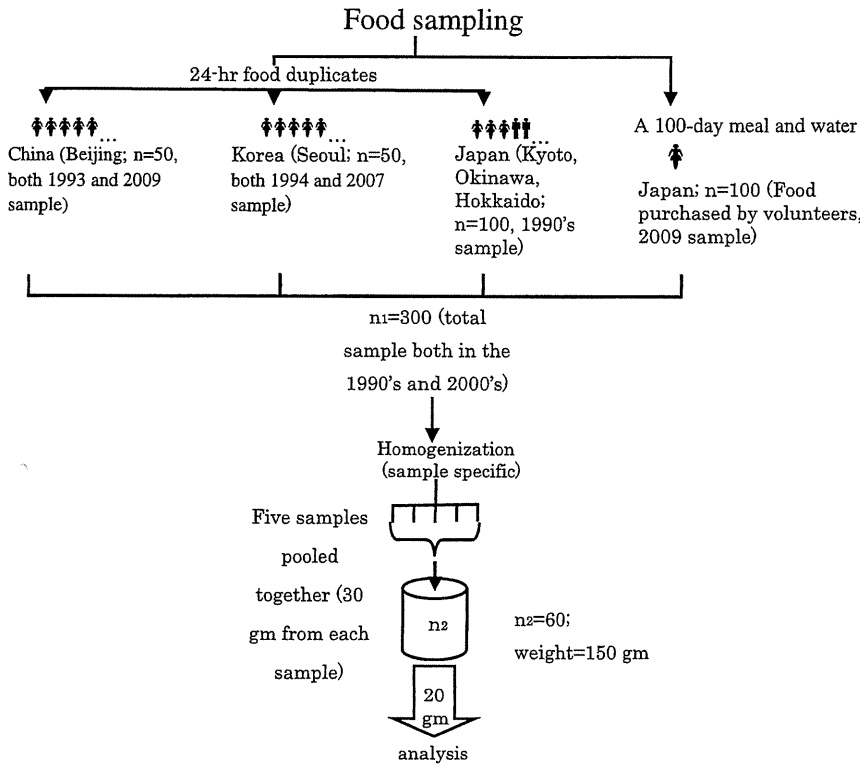

Fig. 1. Schematic presentation of the food sampling process.

2.3. Extraction

Composite samples (20 g) were extracted with 100 mL of 1:1 acetone/hexane (50% v/v). The extracts were filtered and the residues were extracted again with 100 mL of 1:1 acetone/hexane. The extracts were combined and washed with 500 mL of hexane-washed distilled water. The water layer was extracted twice with 50 mL of hexane. The organic layers were combined and washed with 100 mL of hexane-washed distilled water. The organic fraction was dried with anhydrous sodium sulfate and concentrated to ca. 20 mL on a rotary evaporator.

A 2 mL aliquot of crude extract was spiked with internal standards and loaded on an 8 g activated florisil column (Florisil PR; Wako Pure Chemicals, Osaka, Japan) that had been preconditioned with 90 mL of 1:4 dichloromethane/hexane. Toxaphene was eluted with 90 mL of 1:4 dichloromethane/hexane and spiked with $^{13}C_{12}$-2,3,3′,5,5′-pentachlorobiphenyl. The eluate was concentrated to 0.1 mL of decane prior to gas chromatography–mass spectrometry (GC–MS) analysis. α + β-Endosulfan was then eluted with 150 mL of dichloromethane and concentrated in the same manner as toxaphene.

2.4. Instruments and quantification

A high resolution gas chromatography/high resolution mass spectrometry in electron capture negative ionization mode (HRGC/ECNI-HRMS) system was used, which comprised a Hewlett–Packard 6890 Series Gas Chromatograph connected to a Thermoelectron Finningan MAT-95XL (Thermo Electron Corporation, Yokohama, Japan). The separation conditions and target ions are shown in Table 1.

2.5. Quality control

The calibration curves used for quantification consisted of five points covering 0.1–20 ng mL^{-1} in standard solution and were plotted using a linear fit ($r > 0.999$). The method detection limits (MDLs) were 3.0, 1.9, 3.3, 3.6 and 28 pg g^{-1} wet weight for α-endo-

Table 1
GC-MS conditions and selected ions (*m/z*) for the determination of endosulfan and toxaphene.

Target analytes	Endosulfan	Toxaphene
Capillary column	DB-17MS (J&W) 30 m × 0.25 mm (id) 0.25 μm	DB-5MS (J&W) 60 m × 0.32 mm (id) 0.25 μm
Oven temperature	120 °C (1 min)–20 °C min^{-1}–200 °C–10 °C min^{-1}–300 °C (10 min)	120 °C (1 min)–20 °C min^{-1}–200 °C–3 °C min^{-1}–275 °C–20 °C min^{-1}–300 °C min^{-1} (10 min)
Helium gas flow	1.0 mL min^{-1}	1.0 mL min^{-1}
Injection method	On column injection	On column injection
Inlet temperature	120 °C–100 °C min^{-1}–300 °C (10 min)	120 °C–100 °C min^{-1}–300 °C (15 min)
Injection volume	2 μL	2 μL
Ionization	Negative chemical ionization	Negative chemical ionization
Reaction gas	Methane	Methane
Ionizing voltage	70 eV	90 eV
Interface temperature	270 °C	275 °C
Ion source temperature	130 °C	130 °C
	Monitor ions	
	Quantification	Confirmation
Endosulfan	405.8140	403.8169
$^{13}C_9$-endosulfan	414.8436	412.8465
$^{13}C_{12}$-#111-PeCB	337.9207	339.9178
Toxaphene Parlar #26	376.8573	378.8544
Toxaphene Parlar #50	412.8154	414.8124
Toxaphene Parlar #62	376.8387	374.8416
$^{13}C_{10}$-trans-chlordane	419.8254	417.8283
$^{13}C_{12}$-#138-HpCB	407.8398	405.8428

Table 2
Demographic characteristics and average food intakes of the study participants in the 1990s and 2007–2009.

Area	Year	*n*	Sex	Age	HSD test[a]	Height	Weight	BMI	Food intake		HSD test[a]
			male/female	(yr)		(cm)	(kg)		(g d^{-1})	(g kg bw^{-1} d^{-1})	
Beijing	1993	25	0/25	35.5 ± 2.3	A	158.7 ± 2.7	55.0 ± 3.5	21.8 ± 0.9	2249 ± 408	41.0 ± 2.6	AB
	2009	25	0/25	26.5 ± 0.9	B	163.8 ± 2.3	69.8 ± 3.5	26.0 ± 1.9	3054 ± 365	43.8 ± 5.6	A
Seoul	1994	25	0/25	37.8 ± 5.7	A	161.7 ± 0.6	56.3 ± 3.9	21.5 ± 1.6	1777 ± 457	31.7 ± 2.0	C
	2007	25	0/25	35.8 ± 4.0	A	158.5 ± 3.1	53.4 ± 1.7	21.3 ± 0.8	2062 ± 152	38.7 ± 3.1	ABC
Hokkaido	1992, 1995	35	0/35	51.7 ± 4.9	C	150.9 ± 1.6	54.5 ± 2.2	24.0 ± 1.2	2249 ± 274	41.3 ± 5.7	AB
	2009	35[b]	N.A.	N.A.	–	N.A.	N.A.	N.A.	1901 ± 161	37.3 ± 3.2	ABC
Kyoto	1996, 1997	30	0/30	21.5 ± 0.4	B	158.4 ± 1.3	50.7 ± 4.2	20.2 ± 1.9	1740 ± 335	34.4 ± 6.4	BC
	2009	30[b]	N.A.	N.A.	–	N.A.	N.A.	N.A.	1575 ± 73	30.9 ± 1.4	C
Okinawa	1992, 1995	35	15/20	49.4 ± 4.4	C	155.1 ± 6.8	61.8 ± 4.7	25.7 ± 1.8	2614 ± 433	42.4 ± 6.5	AB
	2009	35[b]	N.A.	N.A.	–	N.A.	N.A.	N.A.	1845 ± 137	36.3 ± 2.7	ABC

BMI: body mass index; N.A.: not applicable because of differences in the sampling methods.
Data are presented as the mean ± standard deviation.
[a] Means with different letters differ significantly ($p < 0.05$, Tukey–Kramer HSD test). For example, the letters A and B indicate that the corresponding values differ significantly at $p < 0.05$, while A and AB or AB and B indicate that the corresponding values do not differ.
[b] Food samples were collected by five volunteers.

sulfan, β-endosulfan and toxaphene Parlars #26, #50 and #62, respectively.

Procedural blanks were processed in parallel to every batch of seven samples to check for interference or contamination by solvents and glassware. There were no detectable residues in any of the procedural blanks ($n = 9$).

The recovery rates (mean ± standard deviation) of $^{13}C_9$-α-endosulfan, $^{13}C_9$-β-endosulfan and $^{13}C_{10}$-trans-chlordane were 114.2 ± 14.3%, 108.3 ± 38.4% and 105.0 ± 5.7%, respectively.

2.6. Exposure estimations

A duplicate portion technique was employed to collect food samples. To calculate the actual dietary intakes of endosulfan and toxaphene, the following equation was used:

$$Qx = \sum Cx_i * D \quad (1)$$

where Qx is the total dietary intake of chemical x per d (ng kg bw^{-1} d^{-1}), Cx is the residue level of chemical x (endosulfan or toxaphene) in the food composites (pg g^{-1}), i is the congener or isomer and D is the daily food consumption level (g kg bw^{-1} d^{-1}).

For the 2009 food samples from Japan, the average weight of a Japanese female was used for the exposure estimation. The estimates were based on the 95th percentile of the daily exposure. The estimated intake values were then compared with the acceptable daily intake/tolerable daily intake (ADI/TDI) value of that chemical. We used an ADI value of 6 μg kg bw^{-1} d^{-1} for endosulfan set by the FAO/WHO (Lu, 1995) and an ADI value of 0.2 μg kg bw^{-1} d^{-1} for toxaphene set by the USEPA.

2.7. Data analysis

Data values below the MDL were assumed to have concentrations equal to one-half of the MDL for calculating summary statistics and performing statistical comparisons, except for toxaphene Parlar #62. For values where the proportion of non-detects was small, particularly for endosulfan (10/60 non-detects), the incorporation of these values was assumed to have limited influence on the purpose of our study. However, the non-detect value for Parlar #62 was critical (59/60 non-detects) and we equated it to a zero value, considering the high detection sensitivity of our method and the consistent non-detect values across all groups. All statisti-

Table 3
Levels of endosulfan isomers in the composite food samples and dietary intakes.

	Year (No. of pooled diets)		α-Isomer (pg g fw^{-1})	β-Isomer	Total (ng d^{-1})	Total (ng kg bw^{-1} d^{-1})	HSD test[a]	Intake/TDI (‰)
Beijing	1993 ($n = 5$)	Range ($n >$ MDL)	<3.0–24.2 (3)	<1.9–34.1 (3)	5.5–131.1	0.1–2.3		0.02–0.4
		Mean ± SD	12.5 ± 10.4	16.1 ± 14.8	64.1 ± 56.3	1.20 ± 1.0		0.2 ± 0.2
		GM (GSD)	7.0 (4.1)	6.8 (6.1)	31.6 (5.0)	0.6 (5.2)	A	0.1 (5.2)
		P95 estimate	71.0	133.0	438.0	8.60		1.4
	2009 ($n = 5$)	Range ($n >$ MDL)	180.5–269.3 (5)	288.4–475.3 (5)	1459.5–2242.0	19.2–33.0		3.2–5.5
		Mean ± SD	218.4 ± 41.2	365.5 ± 92.5	1755.6 ± 296.3	25.3 ± 5.0		4.2 ± 0.8
		GM (GSD)	215.4 (1.2)	356.5 (1.3)	1737.0 (1.2)	25.0 (1.2)	B	4.2 (1.2)
		P95 estimate	292.0	534.4	2259.0	34.00		5.7
Seoul	1994 ($n = 5$)	Range ($n >$ MDL)	372.2–544.2 (5)	427.5–1149.1 (5)	1421.0–2999.0	25.6–54.5		4.3–9.1
		Mean ± SD	461.6 ± 76.8	811.4 ± 316.8	2262.3 ± 696.4	40.0 ± 11.2		6.7 ± 1.9
		GM (GSD)	456.5 (1.2)	759.3 (1.5)	2174.4 (1.4)	39.0 (1.3)	B	6.4 (1.3)
		P95 estimate	600.0	1504.0	3664.0	62.00		10.4
	2007 ($n = 5$)	Range ($n >$ MDL)	170.0–7980.0 (5)	170.7–9304.2 (5)	770.0–36 736.5	13.9–714.7		2.3–119.1
		Mean ± SD	2406.0 ± 3198.0	2817.2 ± 3745.0	10 775.0 ± 14 828.7	206.5 ± 289.5		34.4 ± 48.2
		GM (GSD)	1124.0 (4.3)	1262.0 (4.6)	4916.0 (4.3)	92.0 (4.4)	B	15.4 (4.4)
		P95 estimate	12 419.0	15 492.0	54 286.0	1050.00		175.0
Hokkaido	1992, 1995 ($n = 7$)	Range ($n >$ MDL)	<3.0–77.2 (6)	<1.9–156.3 (6)	5.4–446.1	0.1–7.7		0.01–1.3
		Mean ± SD	23.8 ± 25.1	36.4 ± 53.7	128.0 ± 148.5	2.3 ± 2.6		0.4 ± 0.4
		GM (GSD)	14.6 (3.3)	16.5 (4.5)	70.3 (3.8)	1.3 (3.8)	A	0.2 (3.8)
		P95 estimate	104.0	197.0	641.0	11.40		2.0
	2009 ($n = 7$)	Range ($n >$ MDL)	12.1–31.2 (7)	12.5–29.1 (7)	47.9–98.1	0.9–1.9		0.2–0.3
		Mean ± SD	19.0 ± 6.4	20.2 ± 6.1	75.4 ± 22.4	1.5 ± 0.4		0.2 ± 0.1
		GM (GSD)	18.2 (1.4)	19.5 (1.4)	72.3 (1.4)	1.42 (1.4)	A	0.2 (1.4)
		P95 estimate	30.0	32.0	121.5	2.40		0.4
Kyoto	1996, 1997 ($n = 6$)	Range ($n >$ MDL)	<3.0–44.0 (4)	9.7–29.7 (6)	17.8–150.0	0.36–2.94		0.1–0.5
		Mean ± SD	18.9 ± 15.0	17.5 ± 8.1	65.3 ± 46.9	1.29 ± 0.92		0.2 ± 0.2
		GM (GSD)	12.6 (3.2)	15.9 (1.6)	52.7 (2.1)	1.04 (2.1)	A	0.2 (2.1)
		P95 estimate	86.0	34.4	175.0	3.40		0.6
	2009 ($n = 6$)	Range ($n >$ MDL)	<3.0–38.9 (4)	7.6–26.9 (6)	14.1–97.3	0.3–1.9		0.05–0.3
		Mean ± SD	15.6 ± 12.6	16.6 ± 6.6	50.2 ± 27.0	1.0 ± 0.5		0.2 ± 0.1
		GM (GSD)	11.0 (2.9)	15.4 (1.5)	43.5 (1.9)	0.9 (1.9)	A	0.1 (1.9)
		P95 estimate	64.3	31.2	122.3	2.40		0.4
Okinawa	1992, 1995 ($n = 7$)	Range ($n >$ MDL)	<3.0–49.8 (5)	7.8–50.5 (7)	20.4–293.1	0.3–4.4		0.1–0.7
		Mean ± SD	16.1 ± 16.3	21.0 ± 14.9	104.5 ± 95.6	1.6 ± 1.4		0.3 ± 0.2
		GM (GSD)	9.1 (3.7)	17.4 (1.9)	72.0 (2.7)	1.2 (2.6)	A	0.2 (2.6)
		P95 estimate	79.1	50.7	356.0	5.60		1.0
	2009 ($n = 7$)	Range ($n >$ MDL)	<3.0–26.9 (6)	9.2–21.2 (7)	20.0–81.5	0.4–1.6		0.1–0.3
		Mean ± SD	13.4 ± 7.4	15.1 ± 4.2	52.2 ± 18.6	1.0 ± 0.4		0.2 ± 0.1
		GM (GSD)	10.6 (2.5)	14.6 (1.3)	48.7 (1.6)	1.0 (1.6)	A	0.2 (1.6)
		P95 estimate	47.1	23.4	100.0	2.00		0.3

MDL: method detection limit; SD: standard deviation; GM: geometric mean; GSD: geometric standard deviation.
P95 estimates were calculated by multiplying the GM by the GSD to the power of 1.64.
[a] GMs with different letters differ significantly ($p < 0.05$, Tukey–Kramer HSD test). For example, the letters A and B indicate that the corresponding values differ significantly at $p < 0.05$, while A and AB or AB and B indicate that the corresponding values do not differ significantly.

cal analyses was performed using JMP (Version 4; SAS Institute Inc., Cary, NC, USA). The mean, range and geometric mean (GM) were calculated. Since there was a large variation in the concentrations of toxaphene and endosulfan among the groups, the values were log-transformed and differences between the mean values were tested by the Tukey–Kramer honestly significant difference (HSD) test after ANOVA. Residue intake based on the upper 95th percentile limits were calculated by multiplying the GM by the geometric standard deviation (GSD) to the power of 1.64, according to a log-normal distribution. Correlations were tested by Spearman's rank correlation coefficient. Differences were considered to be statistically significant at $p < 0.05$.

3. Results and discussion

3.1. Characteristics of the study participants and pooled sample

A total of 300 samples were collected from the five study sites, as indicated in Fig. 1 and Table 2. A food duplicate sample technique was used to collect the samples, except for the 2009 samples from Japan. The Japanese samples from 2009 were purchased in markets by volunteers, and we assumed average body weight of female aged 26–29 in 2007 in Japan (50.9 kg, National Health and Nutrition Survey in Japan). Apart from a few subjects ($n = 15$) in Okinawa, all the other participants were females. The mean (±SD) age of the participants was 36.5 ± 11.5 years. There were significant differences in the mean ages between time periods in Beijing ($p < 0.05$, Tukey–Kramer HSD test) and these subjects from 2009 appear to be obese (BMI > 25). Food consumption variation was observed among individuals in the groups, which might be a reflection of differences in age, weight and financial situation. These factors may have influenced the choice and amount of food that the subjects consume. However, the intake estimation based on the chemical residues in the food that the subject eats can minimize the introduction of errors, which is a characteristic advantage of the approach used in this study (Hamilton and Crossley, 2004).

Fat content was measured and comparisons were made between time periods because POPs are commonly lipophilic and considered as major source of dietary intake (Fisk et al., 1999). Between time periods, the differences were within twofold's. Among three countries, China had higher fat content (3.90%) in 2009; however, this figure was not consistent with the temporal changes in the intake of endosulfan.

3.2. Trends of endosulfan in the daily consumed food samples

The total detection frequencies of α- and β-endosulfan were 83.3% and 95%, respectively (Table 3). β-Endosulfan was found at relatively high concentrations, which supports the idea that this isomer is more persistent (Sutherland et al., 2004; Berntssen et al., 2008).

The profile of total endosulfan in both time periods in this study was highest in Seoul with a detection frequency of 100% ($n = 10$). The GMs of the α- and β-isomer concentrations were 1124 and 1262 pg g^{-1} in the pooled food composites from Seoul in 2007, respectively. The GMs of the dietary intake of endosulfan in Seoul were 39 ng kg bw^{-1} d^{-1} in 1994 and 92 ng kg bw^{-1} d^{-1} in 2007, and significantly higher than those in Japan ($p < 0.05$, Tukey–Kramer HSD test). The samples from Beijing showed a 50-fold increase in the level of endosulfan from 1993 (GM: 0.6 ng kg bw^{-1} d^{-1}) to 2009 (GM: 25 ng kg bw^{-1} d^{-1}) ($p < 0.05$, Tukey–Kramer HSD test). Among the three areas in Japan, there were no differences in the dietary intake of endosulfan in both time periods ($p > 0.05$, Tukey–Kramer HSD test). Fig. 2 shows log-transformed endosulfan and toxaphene levels in food composite samples where 95% of the values lie inside the boundary of the ellipse. From the figure, it is of interest to note similar increasing pattern of endosulfan in Beijing and Seoul, while a decreasing trend was observed in Japan.

Endosulfan intake in Japan showed a gradual decrease, which may result from reduced agricultural consumption in the country (POPRC, 2009). However, the daily intakes of endosulfan showed increasing trends in Seoul and Beijing by twofold and an order of magnitude in the GMs, respectively. Liu et al. (2010) reported a detected mean endosulfan level of 1.5 ng g^{-1} with variation from non-detects to 13.1 ng g^{-1} in fish samples in Northeastern China. These figures are likely to show high exposure via sea food consumption in the country. The detection of endosulfan in this region was replicated in another study (Guo et al., 2007). In the present study, the significant rise observed in Beijing was in agreement with the endosulfan production history, following its production in 1994 and agricultural application in the country (Jia et al., 2009). Therefore, more importantly, agricultural use could explain the increasing trend. Likewise, Wang et al. (2007) determined high levels of endosulfan in other environmental media in the Northeastern part of Beijing where agricultural land existed.

On the other hand, the concentrations (GM ± GSD) in both Beijing (1737.0 ± 1.2 ng d^{-1}) and Seoul (4916 ± 4.3 ng d^{-1}) were above the 130 ng d^{-1} value in New Zealand (Thomson et al., 2003). China, Korea and New Zealand had been among the remaining users of endosulfan. The food trade between these countries and the Korean reliance on food imports along with the continued use of endosulfan could be another possibility that may somewhat explain the food safety issue. Since food trade partner countries have usually different histories of pesticide use, evaluation of the residue levels and contributions of imported foodstuffs is also worth considering. The variation in concentrations among the pooled samples could also suggest another possibility that individual food types have different contributions, meaning that some groups of people with selective food preferences may be exposed to acutely high-dose.

High levels of endosulfan detection were also reported in Taiwan (Doong et al., 1999), whereas residues of both the α- and β-isomers were not detected in any samples in Jordan (Ahmad et al., 2010). The estimates in Beijing in 2009 and Seoul in both

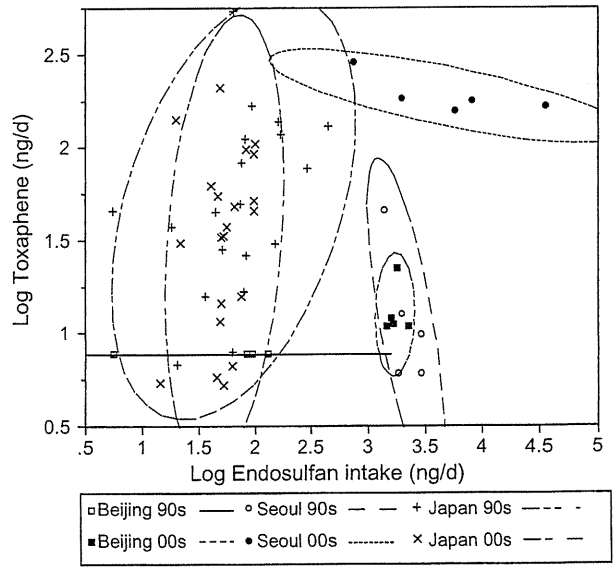

Fig. 2. Plot of the log-transformed endosulfan and toxaphene levels in food composite samples the 1990s and 2000s. Overall, 95% of the values lie inside the boundary ellipse.